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DEPARTMENT OF THE ARMY
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Technical Report 1589-TR

SOLUBILITY CHARACTERISTICS OF RADIOACTIVE
BOMB DEBRIS IN WATER AND EVALUATION OF
SELECTED DECONTAMINATION PROCEDURES

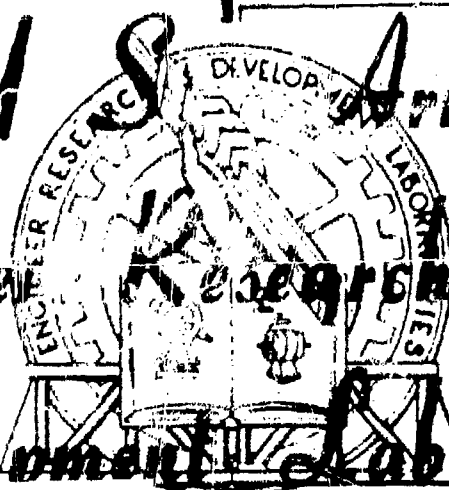
Project 8-75-97-460

12 February 1959

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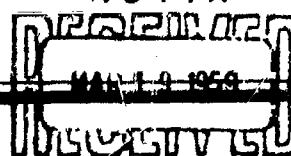
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Technical Report 1569-TR

SOLUBILITY CHARACTERISTICS OF
RADIOACTIVE BOMB DEBRIS IN WATER AND
EVALUATION OF SELECTED DECONTAMINATION PROCEDURES

Project 8-75-C7-460

12 February 1959

Distributed by

The Director
U. S. Army Engineer Research and Development Laboratories
Corps of Engineers

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PREFACE

The investigation covered in this report was conducted under authority of the following:

1. Department of Army Project No. 8-75-07-460, "Removal of CBR Contaminants from Water."

2. Project 50.4, Desert Rock VII and VIII, United States Continental Army Command.

A copy of Project Card 8-75-07-460 (formerly 8-75-07-214) is included as Appendix A.

The period covered by this report is 1 May 1957 to 1 July 1958.

The following personnel were responsible for the acquisition and presentation of the data:

Test Team:

Harry N. Lowe, Jr., Sanitary Engineer, Project Officer
Don C. Lindsten, General Engineer
Paul B. Pruett, Chemical Engineer
William J. Lacy, Radiochemist
M/Sgt Joseph P. Kennedy, Water Supply Specialist

Branch Chief:

Richard P. Schmitt

Department Chief:

Neil K. Dickinson

Appreciation is extended to the Commanding General, Camp Desert Rock, for the excellent cooperation received from all echelons of the Command in support of the activities under Project 50.4, Desert Rock VII and VIII.

Important contributions to these experiments were made by Dr. Richard L. Woodward and Mr. Melvin Crompton, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio; Major Thomas R. Ostrom, MSC, U. S. Army; and Mr. George Goforth, Office of Civil and Defense Mobilization, Battle Creek, Michigan. Dr. Woodward's technical counsel was invaluable in the preparation of the project plan. Mr. Crompton assisted in collecting and sizing the contaminated samples. Major Ostrom's technical review of the test plan

and laboratory procedures on behalf of the U. S. Army Surgeon General was most helpful. Mr. Goforth provided valuable support to the field operations including collecting and sizing contaminated soil samples.

Appreciation is also extended to Mr. J. C. Ledbetter, Personnel Monitoring Section, Health Physics Division, and to Mr. H. A. Parker, Analytical Chemistry Division, ORNL, for their cooperation and assistance in film badge monitoring and in performing some of the radiochemical analysis.

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SUMMARY

This report covers field experiments conducted by the Sanitary Engineering Branch, USAERDL, at Camp Desert Rock, Nevada, to study the water solubility characteristics of radioactive nuclear bomb debris and to evaluate a number of procedures for removing such contaminants from water. These experiments were accomplished on debris obtained from shot PRISCILLA under AEC OPERATION PLUMBBOB at the AEC Nevada Test Site during the summer of 1957. The project was sponsored by the United States Continental Army Command as Project 50.4, Desert Rock VII and VIII. Additional fiscal support was furnished by the Office of Civil and Defense Mobilization, Battle Creek, Michigan.

The more important results of these experiments are summarized as follows:

- a. The radioactive debris resulting from a nuclear detonation was only sparingly soluble in water. The water soluble component dissolved quickly, with but limited additional solution taking place as a result of further agitation and contact time. Increasing the dosage of contaminated soil resulted in a higher concentration of activity in solution. Leaching the same sample a second time resulted in a solution containing less than one half the activity in the first leach.
- b. The solubility of the radioactive debris increased as the pH of the solvent was lowered.
- c. Filtration through dense filter pads or through bonded ceramic elements effectively removed suspended radioactive debris from water. Such filtration followed by demineralization with a column of mixed bed ion exchange resins removed both suspended and dissolved contaminants.
- d. Coagulation followed by filtration was effective in removing suspended contaminants from water but was relatively ineffective in removing the dissolved components of the radioactive debris.
- e. Lime and lime-soda softening were relatively ineffective in removing the dissolved components of radioactive debris from water.
- f. Clay was not effective in removing the dissolved contaminants from water although earlier research had indicated that significant removals of many radioisotopes can be thus achieved.

g. Coagulation followed by filtration followed by demineralization by ion exchange resins removed all of the contaminants, suspended and dissolved components alike.

The report concludes that:

a. Radioactive debris resulting from a normal nuclear detonation is only sparingly soluble in water in the pH range of natural surface waters.

b. Where effective clarification procedures are used, only the dissolved radioactive contaminants will be of importance to those charged with responsibility for the safety of potable water systems.

c. To accomplish complete decontamination, normal water-treating (clarification) processes must be supplemented by distillation, ion exchange, or other processes which remove essentially all dissolved solids from water.

d. The work conducted under Project 50.4 has significantly extended the knowledge concerning water contamination resulting from nuclear bomb debris. However, this work and related studies should be continued and expanded.

SOLUBILITY CHARACTERISTICS OF
RADIOACTIVE BOMB DEBRIS IN WATER AND
EVALUATION OF SELECTED DECONTAMINATION PROCEDURES

I. INTRODUCTION

1. Background and Previous Investigation. The assigned responsibilities of the Corps of Engineers in the field of water supply and sanitation dictate that special consideration be given to the contamination problems associated with the use of nuclear weapons. Previous research has been carried out under Department of Army Projects 8-75-05-008 and 8-75-07-214; both projects were concerned with the decontamination of water contaminated with radioactive substances. Much of the work was accomplished at the Sanitary Engineering Branch Test Station at Oak Ridge, Tennessee, where numerous decontamination studies were made involving a wide assortment of radioisotopes. For many of the experiments, reactor-produced mixed fission products were used, representing the most realistic simulant available for bomb-produced contaminants. The results of these experiments are covered in the 8-75-07-008 and 8-75-07-214 reports available at the Technical Documents Center, USAERDL.

Although the results of the experiments and tests at Oak Ridge have been informative, it has not been possible to evaluate the results in terms of performance under field conditions. Reactor-produced fission products are obtained as soluble ions dissolved in nitric acid. The particulate radioactive debris resulting from the use of nuclear weapons is characterized by different physical, and possibly chemical, properties. Project 50.4 was initiated to verify and extend data already collected in the laboratory. In particular, the objectives of Project 50.4 were to study the solubility characteristics of bomb debris in water and to investigate the effectiveness of selected decontamination procedures in removing these contaminants from water.

II. INVESTIGATION

2. Procedure and Equipment. Project 50.4 was conducted at Camp Desert Rock, Nevada. This camp is located adjacent to the United States Atomic Energy Commission Nevada Test Site (see Fig. 1).

All studies conducted under this project were performed with radioactive debris collected from shot PRISCILLA under AEC operation PLUMBBOB. Shot PRISCILLA was fired at 0630, 24 June 1957,

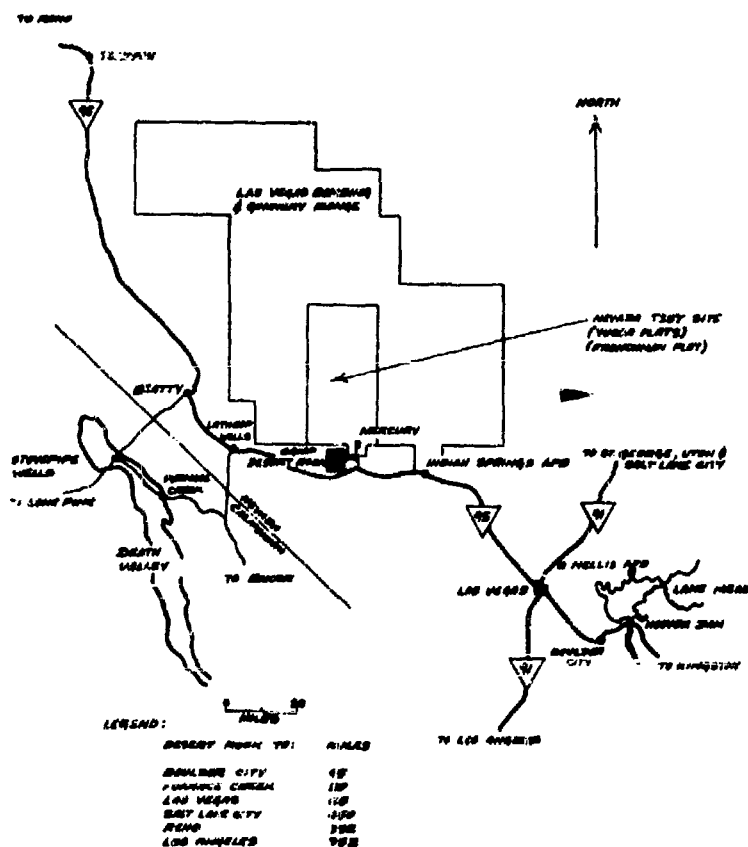


Fig. 1. Camp Desert Rock in relation to the United States Atomic Energy Commission Nevada Test Site and Southern Nevada (map extracted from pamphlet Camp Desert Rock, published by Headquarters Sixth United States Army).

from a suspended balloon on Frenchman Flat at the Nevada Test Site. Prior to the shot day, collecting stations were installed as shown in Fig. 2. A total of ten stations were used, located in a sector of 135 degrees. At each station, five aluminum pans were "dug in" flush with the ground. Each pan measured 30 in. wide, 30 in. long, and 3 in. high. Pans holding water were installed at two stations; two pans were installed at station 3, and one pan was installed at station 5. A 2- by 4-in. wooden stake, painted yellow, was installed vertically at each station in order to mark the site. Film badges were attached to each stake (with tape on the side away from GZ) to measure the gamma ray intensity at each location during and after the detonation.

Fig. 2. Collection stations installed for Project 50.4 for shot PRISCILLA.

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One and one-half to three hours after the firing of shot PRISCILLA, a radiological monitoring survey was made by the Rad-Safe Office, Camp Desert Rock at each of the ten collection stations. During the period 1 to 12 hours after detonation, another radiological survey was conducted by project 50.4 personnel at each of the ten stations, and the film badges were removed to be analyzed at the Oak Ridge National Laboratory (ORNL) for integrated dose.

Two days after the shot, the fallout was collected from the pans and was sized and a portion of each sample was shipped to the Taft Sanitary Engineering Center, Cincinnati, Ohio, for analysis and study. Sizing was accomplished with a special sub-sieve-sizer developed at the Taft Center. By means of this apparatus, samples of less than 5 microns, 5 to 50 microns, and over 50 microns were obtained. Results of the work done at the Taft Center will be reported by United States Public Health Service in a separate report.

Samples of radioactive debris obtained in the vicinity of ground zero were used for most of the studies under Project 50.4. These studies were made at a laboratory installation adjacent to Camp Desert Rock. This installation consisted primarily of a mobile chemical laboratory and a mobile radiac laboratory (see Fig. 3).



E2926

Fig. 3. Mobile Radiac Laboratory (on left in rear), Mobile Chemical Laboratory (on right in rear), and test personnel (left to right), Lacy, Lowe, Lindsten, Pruett, and M/Sgt Kennedy.

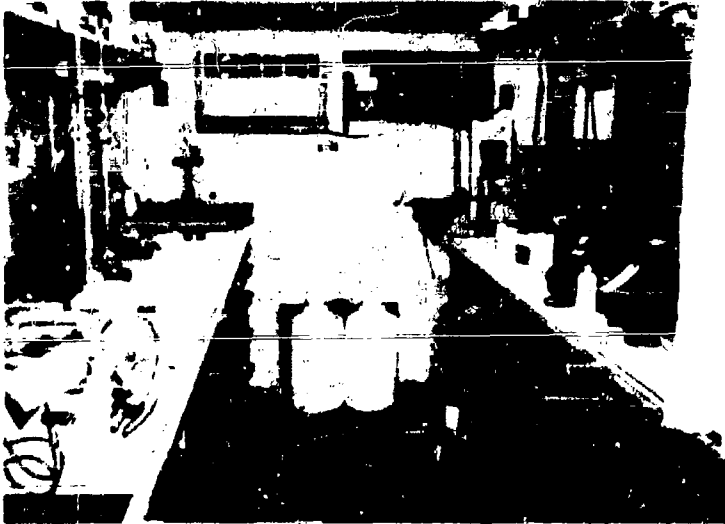
All chemical tests and jar test experiments were conducted in the chemical laboratory, and all counting was conducted in the radiac laboratory. Both laboratories were electrified; power was furnished by a 10-KW, gasoline-engine-driven, electric generator mounted on a 1½-ton cargo trailer. Figure 4 shows an interior view of the chemical laboratory, and Fig. 5 shows an interior view of the radiac laboratory. Other small samples were shipped to ORNL for analysis as a check on the accuracy of field laboratory procedures. A quantity of debris was studied at Fort Belvoir to confirm results obtained using the lime-soda process. Film badge monitoring was accomplished at no cost to this project by the Health Physics Division, ORNL.

The most significant piece of equipment used for the solubility and decontamination studies of radioactive debris in water was the jar test apparatus shown in Fig. 6. By means of this apparatus, various parameters were studied. For a simple water leaching study, a 1-gallon bottle was used (see Fig. 7). Standard Army "Water Purification Unit, Hand-Operated, Knapsack-Pack, Filter-Pad-Type 1/4 GPM" was used for certain decontamination experiments involving filtration (see Fig. 8).

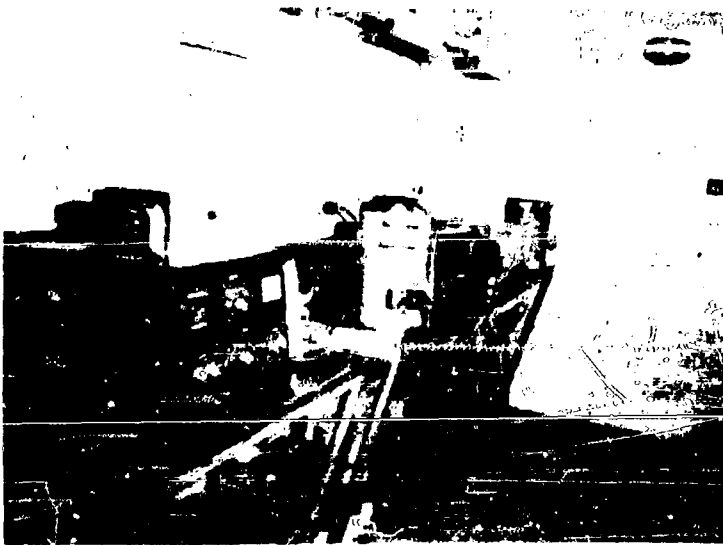
A commercially available small filter unit was used in certain other filtration experiments. This unit termed FILTERPURE is manufactured by the American Katadyn Corporation, Stamford, Connecticut. The unit consists essentially of a silver impregnated ceramic filter candle contained in a suitable housing and equipped with a hand pump for forcing water through the candle (see Fig. 9).

For a number of the ion exchange experiments, a Lamotte FILTR-ION unit was used. This unit consists of ion exchange resins contained in a plastic shell (see Fig. 10). In other experiments, ion exchange resins were used in plastic tubes assembled in the laboratory.

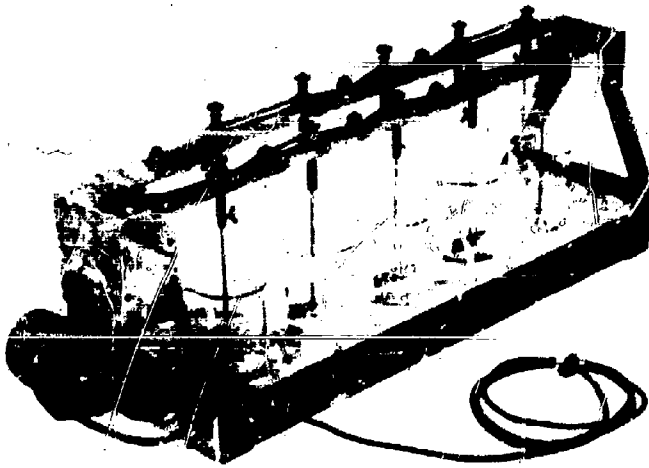
All counting was done with a Nuclear Chicago Model 162 scaler (Serial No. X-50366) and lead shield. A 2.6 mg/cm² Geiger-Muller tube was used in the top shelf of the shield; the Geiger-Muller tube was sensitive to beta emanation, but quite insensitive to gamma radiation. During the period 24 June 1957 to 15 July 1957 inclusive, a Tracerlab GM tube was used having a geometry of 5.6 percent, as standardized with thallium 204. From 16 July 1957 to 24 July 1957, inclusive, a Nuclear-Chicago GM tube was used with a geometry of 3.9 percent. Figure 11 is a photograph of the counting equipment used. Results from counting done at ORNL at later dates were reported on a 10-percent geometry basis, but were recalculated on a 5.6- or 3.9-percent geometry basis to permit direct comparison of data.



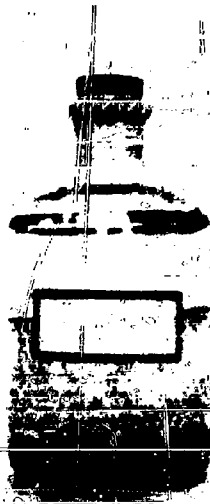
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Fig. 4. Interior view of Mobile Chemical Laboratory used for Project 50.4.



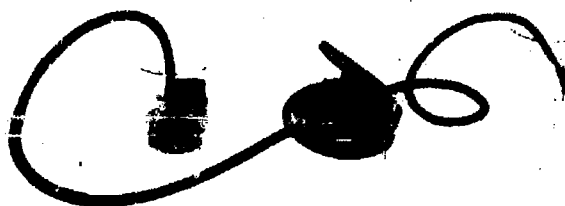
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Fig. 5. Interior view of Mobile Radiac Laboratory used for Project 50.4.



E2666
Fig. 6. Jar test apparatus used for laboratory-scale water solubility and decontamination studies.



E2923
Fig. 7. One-gallon bottle used for water leaching studies.



E2920

Fig. 8. "Water Purification Unit, Hand-Operated, Knapsack-Pack, Filter-Pad-Type, $\frac{1}{4}$ GPM" used in certain decontamination studies involving filtration.



E2663

Fig. 9. Katadyn FILTERPURE filter unit used for removing suspended material from water contaminated with radioactive substances.

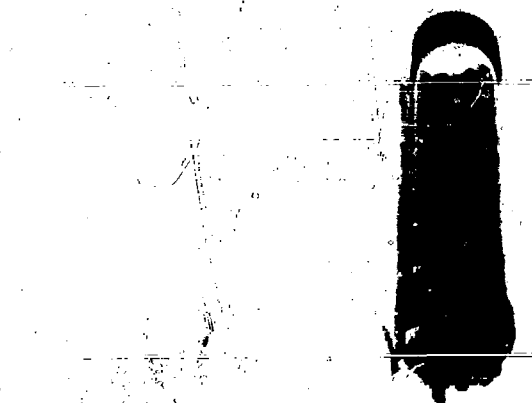


Fig. 10. Lamotte FILTER-ION unit used for laboratory ion exchange experiments. E2664



Fig. 11. Counting equipment used for Project 50.4. Note lead shield on left and Nuclear-Chicago scaler in center (HTL Rectifier on right used for recording gamma background). E2921



Fig. 12. Exploded view of air filtration unit used to check laboratory area for airborne radioactive particulates. E2922



Fig. 13. Air filtration unit installed in louvered shelter. E2927

As an auxiliary item, an air filtration station was installed outside one of the barracks in Camp Desert Rock. This unit, housed in a louvered shelter, was a Gast Model AD 440-3 filter used and distributed by the New York Operations Office, AEC. It operates on 110-volt, 60-cycle alternating current and is equipped with an electric timer to permit 15 min on-45 min off operation. The air filtration rate is approximately 50 cfm. An exploded view of the unit is shown in Fig. 12, and the unit installed in its louvered shelter is shown in Fig. 13.

Precautionary measures were taken by all personnel to avoid unnecessary exposure to radioactive materials or to radiation fields. Geiger-Müller and ionization-type radiation survey meters were used to check the Priscilla shot area before entry by any member of the test team. Protective clothing was worn by personnel at all times when collecting bomb debris or when entering the area for any other purpose after detonation. Protective clothing consisted of cloth coveralls and cap, and rubber shoe covers and gloves. During periods of windy or dusty weather, each man wore a Mine Safety Appliance respirator to eliminate the hazard of inhaling radioactive particulates. Each man carried a self-reading 0 to 5 roentgen dosimeter and a film badge. The self-reading dosimeter enabled each member of the test team to determine instantly his cumulative exposure. Each film badge was collected at the end of the test period and submitted to the Desert Rock Rad-Safe Division for determination of each individual's total radiation dose.

3. Results. The radiation readings taken at each fallout station by Desert Rock Rad-Safe personnel are shown in Table I.

Table I. Radiation Readings at Fallout Stations
After Shot Priscilla
(Measured by Desert Rock Rad-Safe Personnel)

Station	Time (24 June 1957)	Radiation Flux (mr/hr)
1	0810	5
2	0840	32
3	0847	34
4	0853	2
5	0900	20
6	0904	180
7	0907	170
8	0910	300
9	0913	75
10	0917	3

NOTE: Priscilla shot time 0630, 24 June 1957.

Radiation and other observations taken by Project 50.4 personnel at each fallout station 10 to 12 hours after detonation of shot PRISCILLA are shown in Tables II and III.

Table II. Radiation and Other Observations
at Fallout Stations After Shot PRISCILLA

Sta- tion	Time (24 June 1957)	Radi- ation Flux (mr/hr)	Condition of Station		
			Film Badges Remaining	2" x 4" Wood Support	Pans
1	1715	0.2	5	Upright, charred	Intact
2	1658	15.	4	Broken off, charred	Intact, filled with dust and sage
3	1735	20.	5	Broken off	Intact
4	1745	0.3	5	Upright, no charring	Intact
5	1804	14.	1	Upright, charred	One pan thrown 10 ft from site
6	1801	300.	5	Upright, charred	Intact
7	1825	370.	5	Upright, charred	Intact
8	1830	450.	0	Broken off	One pan thrown forward
9	1838	160.	1	Upright	Intact
10	1850	0.8	5	Upright	Intact

NOTE: Priscilla Shot Time 0630, 24 June 1957

Laboratory scale solubility and decontamination experiment data are shown in Appendix B.

Air filtration data are shown in Table IV.

Table III. Film Badge Data

Exposure Time at Removal of Film Badge	Radiation Flux At Time of Removal of Film Badge (mr/hr)	Film Badge* Sensitive Film (Cumulative mr)	Film Badge Insensitive Film (Cumulative mr)
10 hr 45 min	0.2	8550	-
10 hr 28 min	0.5	>10000	>20000
11 hr 5 min	20.	>10000	>20000
11 hr 15 min	0.3	1810	-
11 hr 34 min	14.	>10000	>20000
11 hr 31 min	300.	>10000	19700
11 hr 55 min	370.	>10000	>20000
12 hr 8 min	160.	>10000	>20000
12 hr 20 min	0.8	4500	-

NOTE: Priscilla shot time 0630, 24 June 1957

* Developed and read by personnel of Health Physics Division, ORNL.

Table IV. Air Filtration Data

Filter Pad Number	Filtration Period (1957)	Date of Analysis	Radioactive Count (c/m/pad)
1	2300, 22 June - 0700, 23 June	2 July	72
2	0700, 23 June - 0700, 24 June	2 July	72
3	0700, 24 June - 1935, 25 June	2 July	37
4	1935, 25 June - 0900, 27 June	2 July	59
5	0900, 27 June - 0800, 12 July	12 July	3760
		13 July	3437
		15 July	2912
6	0800, 12 July - 0800, 19 July	19 July	863

NOTE: Shot Schedule During Period 22 June - 19 July 1957:

25 June, 5 July, 15 July, 19 July

Total integrated radiation dosages received by members of the test team during the entire period of operations are shown in Table V.

Table V. Radiation Dose Received by Members of Test Team

Name	MR Dosage
M/Sgt Joseph Kennedy	265
William J. Lacy	35
Don C. Lindsten	540
Harry N. Lowe, Jr.	370
Paul B. Pruett	175

RADIATION TOLERANCES: 3 R in any consecutive 13-week period.
5 R in any one year.

An analysis of the data in the tables and in the Appendix leads to the following results and observations:

a. Contamination Levels at Sampling Stations. Contamination levels at the ten sampling stations were uniformly low, readings at from H + 1.6 hours to H + 2.8 hours ranging from 2 mr/hr to 300 mr/hr, while readings at the same sites at from H + 10.5 hours to H + 12.5 hours ranged from 0.2 to 450 mr/hr. The higher readings at the later time were recorded at stations downwind of ground zero.

b. Activity in Size Fractions. The contaminated soil was separated into three size fractions -- greater than 50 microns, from 50 to 5 microns, and less than 5 microns in particle size. It was found that the fraction 5 to 50 microns contained more activity per gram than either of the other two fractions; the ratio being approximately 3 to 2.

c. Solubility as a Function of Contact Time. Solubility of the active component of the radioactive debris was found to vary only slightly with time of contact at constant rate of agitation and soil dosage. For example, material in solution after one minute of contact was 77 percent as great as that in solution after one hour.

d. Solubility as a Function of Debris Concentration. Material in solution increased with each increase in the amount of contaminated soil in contact with the water between 100 ppm and 100,000 ppm debris by weight. The rate of increase was not, however, directly proportional to the debris concentration. For example, 10,000 ppm of debris produced a solution of 27 c/m/5ml while 100,000 ppm of debris produced a solution of 120 c/m/5ml.

e. Solubility as a Function of Particle Size. The solubility of the active component of radioactive debris in water varied

with the particle size of the gross sample. For example, a sample of debris less than 5 microns in size gave 85 c/m/5ml when agitated in distilled water; whereas an equal weight of debris in the range 5 to 50 microns gave only 30 c/m/5ml. Since the 5 to 50 microns fraction contained approximately 1.5 times the contamination in the less than 5 microns fraction, the solubility of the radioactive component of the latter was approximately 4.25 times that of the coarser fraction. It is recognized that the solubility of any size fraction is not necessarily dependent upon the size per se, but upon associated characteristics such as density and chemical composition.

f. Solubility by Series Leaching. Series leaching was evaluated in experiment 28. A sample of debris was leached with distilled water. The supernatant liquid was decanted, and the resulting sludge was re-leached with additional distilled water. The first leach gave 52 c/m/5ml, and the second leach gave 21 c/m/5ml. It may be assumed that additional leaching would have shown even further diminution in soluble material.

g. Solubility as a Function of pH. The solubility of the active component of radioactive debris in water as a function of pH, low pH giving greater solubility. For example, in experiment 10, debris agitated in distilled water gave 250 c/m/5ml at pH 3.2, whereas agitation at pH 10.4 gave only 70 c/m/5ml.

h. Solubility in Acid. Hydrochloric acid was found to be slightly less effective than nitric acid in dissolving debris obtained near ground zero. Precipitation of 63 to 68 percent of the dissolved activity was observed as the pH of the acid solution was raised from 2.8 to 10.4. This may have been due to the formation of the insoluble hydroxides of zirconium, niobium, yttrium, and the rare earths.

i. Solubility by Quiescent Leaching. The solubility of the active component of radioactive debris in water by quiescent leaching is essentially independent of time of standing. Results of the first 5 days of leaching indicated no significant increase in dissolved radioactivity after 1 hour of contact. The daily increase in dissolved materials was apparently just sufficient to balance the daily loss through decay. Beyond 5 days, an appreciable drop in dissolved activity was noted, due primarily to radioactive decay.

j. Preparation of Stock Supply of Contaminated Water. The preparation of a stock supply of water for experiments 17 through 27 is of interest. A total of 208 pounds of soil collected 30 yards northeast of ground zero was vigorously agitated for $1\frac{1}{2}$ hours with 250 gallons of tap water in a 500-gallon tank. The water

was then settled. Prior to slurring, the soil was analysed for gross count, giving 13,000 counts per minute per gram. With the supernatant reading 107 c/m/5ml (filtered, and at 5.6-percent geometry), a solubility of 1.63 percent was indicated. The supernatant was submitted to a radiochemical analysis 2½ months later, when, with the gross count reading 53 c/m/5ml at 5.6 percent geometry, the radioactive component analyzed 43 percent radiocesium, 15 percent radiostrontium, 24 percent trivalent rare earths, and 18 percent unidentified isotopes.

k. Removal of Radiocolloids. Under favorable conditions of pH, a significant amount of the contaminant was present in water as radiocolloids. The colloids were filterable through a biological filter only. They were effectively removed by coagulation with ferric chloride and pulverized limestone followed by filtration.

l. Decontamination with Clay. Treatment with clay was ineffective in removing dissolved activity from water. In experiment 22, for example, it was noted that 500 to 1500 ppm Belvoir clay removed only 2 to 10 percent of the activity. In this connection, it should be noted that the radioactivity was obtained in association with large amounts of soil. It was not possible, therefore, to contaminate water with this mixture without, in effect, clay treating the water at the same time. The activity in solution was that material which was not readily removed by clay.

m. Decontamination by Coagulation and Filtration. Coagulation and filtration were very effective in removing suspended activity from water, but were relatively ineffective in removing dissolved activity from water. Recapitulated data on removing dissolved activity are shown in the Table VI.

Table VI. Removal of Dissolved Activity
by Coagulation and Filtration

Experi- ment	Contaminated Water	Coagulants	Range of Removal of Dissolved Activity (%)
3	Water in pan, station 8	$\text{FeCl}_3\text{-CaCO}_3$	16-30
5	Ditch water, Frenchman Flat	$\text{FeCl}_3\text{-CaCO}_3$	8-36
17,18	Supernatant, debris mixed with tap water	FeCl_3	25-54
17	" " "	$\text{Al}_2(\text{SO}_4)_3$.	4-25
		K_2SO_4	
19	" " "	$\text{FeCl}_3\text{-Na}_2\text{CO}_3$	13-46
20	" " "	$\text{FeCl}_3\text{-CaCO}_3$	4-29
21	" " "	$\text{FeCl}_3\text{-Ca}(\text{OH})_2$	4-16

n. Decontamination by Filtration Followed by Demineralization. Filtration with "Water Purification Unit, Hand-Operated, Knapsack-Pack, Filter-Pad-Type, $\frac{1}{4}$ GPM" (Set No. 1), to remove turbidity, followed by demineralization with mixed bed ion exchange material was an effective method of removing activity from contaminated water. A 100-percent removal was demonstrated in experiment 4.

o. Decontamination by the Process Coagulation-Filtration-Ion Exchange. Coagulation, filtration, and demineralization by ion exchange, taking place in that order, was an effective method of removing total activity, suspended and dissolved, from contaminated water. Table VII summarizes data obtained.

Table VII. Decontamination by the Process
Coagulation-Filtration-Ion Exchange

Experiment	Contaminated Water	Process	Removal of Total Activity (%)
6	Ditch water, Frenchman Flat	Coagulation Filtration Mixed bed ion exchange	100
23	Supernatant, debris mixed with tap water	Coagulation Filtration	25
	"	Coagulation, Filtration, Cation ion exchange	58
	"	Coagulation Filtration, Anion ion exchange	93
	"	Coagulation Filtration Mixed bed ion exchange	100
	"	Coagulation, Filtration, Cation ion exchange and anion ion exchange in series	100

p. Decontamination by Softening. Softening was relatively ineffective in removing dissolved activity from water, as shown by the composite results in Table VIII.

Table VIII. Decontamination by Softening

Experiment	Contaminated Water	Softening Chemicals	Range of Removal of Dissolved Activity (%)
24	Supernatant, debris mixed with tap water	$\text{Ca(OH)}_2\text{-Na}_2\text{CO}_3$	20-43
30	Supernatant, debris mixed with Shenandoah River Water	$\text{Ca(OH)}_2\text{-Na}_2\text{CO}_3$	25-31

q. Decontamination with Adsorbent Materials. During the past several years, numerous materials were screened for their ability to remove radionuclides from water. A number of these were tested in this series of experiments using contaminated tap water. The procedure in each case was to slurry the material in the settled water and then to filter the water through a paper towel. Results were as shown in Table IX.

Table IX. Decontamination with Adsorbent Materials

Adsorbent Material	Activity Removed (%)
Steel wool	0
Toilet tissue	22
White pine saw dust	9
Oak saw dust	11
Coffee grounds	35
Red soil (high in iron)	43

III. DISCUSSION

4. General. The work reported herein was devoted to a study of bomb debris from only one test shot in a series of tests at the Nevada Test Site. The number of samples collected and the studies conducted consumed the maximum effort of available personnel within

established funding limitations. Essential to the expansion of the originally proposed military research program was the fiscal support provided by the Office of Civil and Defense Mobilization, Battle Creek, Michigan.

The planned work was accomplished, and schedules were maintained in all cases except where delays were encountered due to weather or necessary security and/or safety requirements. No significant difficulty was experienced in the use of Damp Desert Rock as a laboratory site. Arrangements permitting more ready access to Camp Mercury would have been helpful. The program was penalized by the generally low level of contamination resulting from shot PRISCILLA and by the unusually large amount of dust in the test area. Due to this dust, it was not possible to collect radioactive debris except in association with large amounts of soil. The low levels of contamination generally slowed the laboratory work and made it impractical to accomplish significant radiochemical analyses in some instances. However, in spite of the difficulties, this study has significantly extended the knowledge concerning water contamination resulting from nuclear bomb debris.

Throughout this study and this report, reference has been made to bomb debris rather than to fallout. The radioactivity in proximity to ground zero is a composite of mixed fission products and "radioactive junk" consisting of soil and parts of structures in the target area that were inside the zone of significant neutron radiation. Much of this material is in the form of relatively large particles that return to earth rather quickly. Some fission products are not immediately formed in the bomb burst and may be found in more abundance in the high level cloud than in the immediate area of the target. In addition, fallout at considerable distance from a target area may occur only days or weeks after a detonation and will contain a higher percentage of long lived materials than that found close to ground zero shortly after H-hour. Particularly with regard to water solubility, the data presented herein should be evaluated in terms of radioactive debris rather than fallout, although further study may demonstrate that the difference in practical terms may not be large.

5. Water-Treating Processes. A number of the experiments performed under this project were intended merely to demonstrate in the field certain water-treating processes that had been studied at length in the laboratory. Among these were chemical coagulation followed by filtration and demineralization using ion exchange resins. The performance achieved on bomb debris was in general agreement with the expected results.

By coagulation and filtration, one may reasonably expect to remove essentially all suspended matter from water. This not only applies to radioactive materials but to suspended soil particles, precipitated chemicals, and most bacteria as well. Removal of essentially all suspended matter is routinely accomplished in many water plants. In several of the experiments reported herein, it was noted that radioactive colloids existed under favorable pH conditions. This, too, is not a new experience in water treatment; a similar problem exists frequently with the handling of high turbidity waters in regions containing clays. It should not be assumed, however, that all suspended radioactive materials would be removed by normal operation of any given municipal water treatment plant. Unfortunately, many plants in this country do not produce a polished effluent. Many such plants can be made to produce water of high clarity by changes in operation and/or by improved chemical control. The results of this study emphasize the importance of removing all suspended matter in treating contaminated water since the majority of the contaminant remained in suspension; less than 2 percent appeared in solution.

The removal of all measurable amounts of dissolved (ionic) radioactivity by ion exchange resins was expected. The capabilities of ion exchange resins are well documented and have been proved in wide use in AEC activities and elsewhere. The effectiveness of any demineralization process in removing dissolved radionuclides from water is generally proportional to the overall removal of dissolved solids. Not demonstrated in this test is that significant removal of radionuclides can be achieved under favorable conditions after the resin capacity to removed calcium salts has been exceeded.

6. Experimental Data. The data collected under this project are essentially the only technical guidance now available concerning the water solubility of bomb debris. It would be desirable if these data presented a complete picture of what one may expect in time of war, under all conditions of weapon types, methods of employment, weather, topography and geology. Such is not the case. This study must be considered as only one step toward the desired understanding of water contamination to be expected in a nuclear war. On the other hand, it is essentially that available information be evaluated and used concurrently with efforts to extend basic knowledge and understanding. For this reason, it appears desirable to supplement this discussion by referring to the laboratory results reported under Department of Army Project 3-75-07-214 and to the very limited experience resulting from field work under AFSWP Project Jangle 6.8 (1951). The sum of all this experience is not large; for this reason, a number of the conclusions advanced later in this discussion should be considered only as tentative, requiring review and revision as new data become available. It is considered quite probable that some

of the data resulting from this study will take on new significance and importance when supplemented by future work that provides enough additional data to establish a firmer basis for interpretation. Of importance also is the fact that the skill of the test team and the choice of laboratory procedures improved during this study period. This had no significant effect on the overall findings, but it is felt that in this study opportunity has been provided to work out procedures that will be valuable in guiding and reducing the cost of future work. For example, in this study suspended matter was removed by a centrifuge, Whatman 54 and Whatman 42 filter paper and by a membrane filter disk. In each case, the goal was to separate suspended radioactivity from that in solution within the limits of a definition meaningful to the study at hand. Satisfactory reproducible results were more readily achieved with the membrane filter, and this should become the standard procedure in future work.

It does not appear practical to attempt to estimate the maximum ground contamination to be expected during a nuclear war. Even a low yield weapon detonated on or immediately under the surface of the ground may result in very heavy contamination in the immediate area of the target. On the other hand, kiloton range atomic weapons detonated at heights exceeding the fire ball radius do not heavily contaminate the target area. So-called "dirty" weapons in the megaton range have the capability of heavily contaminating large areas. The important feature is that experience demonstrates that while the magnitude of ground contamination may vary over a wide range, the use of tactical or strategic nuclear weapons against surface targets will result in measurable contamination of the ground in the target areas.

The radiation readings at the collecting stations are shown in Table I. The radiation flux at these stations was not high and would have permitted personnel to work in these areas for extended periods under emergency conditions. The film badge data and other observations listed in Tables II and III point up the significance of prompt radiation, thermal radiation, and blast effects as opposed to the residual radiation at these stations subsequent to the shot and the die-out of the fire ball.

a. Experiment 3. Experiment 3 was the first experience with the large volume of dust that was displaced by the blast and which indirectly contributed to the failure to develop data of value in this experiment. The very limited amount of sample prevented a repeat of the experiment. In recovering the sample, all of the dirt in the collecting pan was recovered along with the water. This resulted in a sample so turbid that clarification of it by single-step coagulation was not effective. Subsequent observations indicated that a significant amount of the solids was colloidal in size and

would not settle out even after long standing. It was estimated that the dirt collected with the water sample was not less than 25 percent by weight. Since no effective flocculation was achieved and the suspended solids were not effectively removed at any point in the experiment, the data are of no significance. To permit completion of the calculations, the removal of turbidity is shown as 100 percent (assumed) notwithstanding the above-noted fact that nothing approaching this was actually achieved. Observations made during this initial period demonstrated conclusively that the general level of contamination in the areas of the collecting pans was so low that little effective work could be performed with so little radioactivity and so much associated dirt. High winds in the several days immediately following the shot added to the accumulation of dust in the area.

b. Experiment 4. Experiment 4 was an attempt to obtain at least one set of data using contaminants from the collecting pans. The data are considered significant. The raw water was filtered through a standard Corps of Engineers Water Purification Set No. 1 filter pad. Radioactivity passing this filter can be assumed to be in solution. The amount passing was approximately 3.25 percent, a figure consistent with later findings using soil from very near ground zero. In this experiment using raw water of moderate turbidity, effective coagulation was achieved. The activity was reduced 92 percent by coagulation and settling. This is not a surprising performance in light of findings in other prior research. The indicated removal after centrifuging was higher than anticipated. Assuming that the dissolved activity was 7 c/m/5 ml and that all of the suspended solids were removed, the residual of 0.8 c/m/5 ml indicates removal of the dissolved activity by coagulation of 88.5 percent. The radiochemical data indicated a gross beta reduction of 60 percent and relatively high percentages of radiocesium and radiostrontium. The levels of radioactivity in the treated water samples were so low throughout these experiments that the radiochemical data must be evaluated with extreme caution. Radiostrontium contributed 20 percent of the beta activity in the raw water and slightly more than 6 percent in the filtrate (dissolved).

c. Experiments 5 through 7. To obtain more significant levels of contamination, it was necessary at this point to abandon the collecting sites and to use soil from near ground zero. Due to security restrictions, collection of this material was delayed several days. In the interim, attention was given to a totally unexpected source of contaminated water, a water-filled ditch on the otherwise dry lake bed located approximately 125 yards NE of GZ. This water was the remaining portion of the spring run-off and it, too, later evaporated. A check made before the test shot showed a gross count of 12 c/m/5 ml. This water was exceptionally clear, and

all or most of this activity was in solution. Although no radiochemical analysis was made, it can be assumed that the activity present consisted largely of radiostrontium, radiocesium, and other long lived isotopes in that this contamination could not have come from other than shots fired in previous series months or even years earlier. This was recognized as an interesting source, and the study was continued after shot PRISCILLA. Experiments 5, 6, and 7 were conducted using this ditch water; in Experiment 7, the work was accomplished in the field. The important features of these experiences can be summarized as follows:

(1) A surface water supply in a former target area contained measurable contamination (12 c/m/5 ml), and almost all of this activity can be reasonably assumed to be in solution.

(2) This same source was not grossly contaminated by shot PRISCILLA, although it was relatively close to GZ. The activity count was raised from the pre-shot level of 12 c/m/5 ml to 25 c/m/5 ml one week after the shot, and the latter figure included some filterable contaminant. Reductions by coagulation and filtration ranged from 8 to 57 percent. The addition of local clay to the water did not improve the removals.

(3) Complete removals were achieved by ion exchange demineralization.

(4) Radiostrontium ranged from 15 to 22 percent of the residual activity after treatment. This last-noted finding may be significant and shall be considered at some length later in this discussion.

d. Experiments 8 and 9. Experiments 8 and 9 were devoted to a study of the effects of agitation on solubility in tap water and in distilled water. For periods longer than 5 minutes, no significant increase in the dissolved components was demonstrated with respect to either time or the choice between tap water and distilled water. Of the radioactivity in solution, the chemical analysis reported in Experiment 9 showed 28 percent as radiostrontium and only 2 percent as radiocesium.

e. Experiment 10. In Experiment 10, the data suggest that pH over normal ranges has only limited effect on the amount of contaminant going into solution. As might be anticipated, solubility increased significantly as the pH was lowered sufficiently to remove the MO alkalinity. The radiochemical data showed dissolved radiostrontium increased with pH while the trivalent rare earths decreased as the pH was lowered.

f. Experiments 11 and 12. An increase in dissolved activity with each increase in the concentration of the contaminated soil was expected as demonstrated in Experiment 11. It should be noted, however, that the increase in activity was not directly proportional to the soil concentration. A test to evaluate water leaching produced the results shown in Experiment 12. These data suggest that water in contact with contaminated soil (as in a pond) may reach its maximum load of contaminant in solution in a relatively short time and that this will not increase with time of contact. Results after 48 and 72 hours of leaching indicate that there was very little radioactivity in suspension in the supernatant. It is felt that this emphasizes that settled water such as might occur in reservoirs will not normally contain much suspended contaminant after several days of settling and that field survey readings of low turbidity waters may be assumed to represent dissolved materials. This assumption would be weakened by the presence of colloidal size particles or small amounts of turbidity kept in suspension by wave action or other factors preventing normal settling. In the case of fallout consisting of only very fine particles, question might be raised as to whether such particles will settle at all within practical terms.

7. General Results and Findings. The importance of the work done in Experiment 13 has little bearing on field water supply problems. It was performed to provide additional information on which to evaluate earlier work by these authors and others using reactor-produced fission products. Some of this earlier work was done a number of years ago under Department of Army Projects 8-75-07-214 and 8-75-05-008 at ORNL. In these experiments, fission products dissolved in acids were added to tanks of tap water or local creek water to provide a contaminated supply. In the absence of observations to the contrary, it was assumed that the radionuclides remained in solution in the contaminated water supply. Results achieved using chemical coagulants, lime softening, and phosphates were reported in terms of removal of contaminants from solution. Study of these data revealed two trends considered to warrant additional thought and interpretation:

Performance of coagulants was erratic with low dosages of coagulants frequently giving better results than higher dosages. Coagulation with alum and with ferric chloride sometimes produced better results when used with added alkalinity than when used alone even when the dosage of the coagulant was the same and adequate natural alkalinity was available for completion of the chemical precipitation of a good floc.

Removals by lime or lime soda softening processes were not directly proportional to softening achieved, occasional good removals being reported when little or no softening was accomplished.

These results suggested that the activity in the initial acid solution might have been precipitated in part after it was put in the higher pH environment of the raw water and that the removals achieved were more related to pH than to the flocculation achieved in the several processes. The results shown in Experiment 13 tend to support this explanation. For example, under the conditions of the experiment using hydrochloric acid and sodium hydroxide an apparent removal of more than 50 percent was achieved by raising the pH of the raw water from 6.2 to 10.5. This entire matter is more indicative of oversight during previous researches than any new knowledge. Considering the very limited amount of research done thus far on water decontamination, it is possible that there may be areas of previous work that deserve further study or reappraisal. The unusually high removal of activity from certain test waters by filtration with Corps of Engineers Water Filtration Set No. 1 may thus be explained. The practical importance of pH control in water decontamination from bomb debris may not be great since the effects of pH shown in Experiment 10 were not truly significant until the pH was depressed below 6.0. An example of decontamination by mechanisms other than softening is shown in Experiment 16. In this experiment, some precipitation resulted from the addition of lime but no softening was achieved. This water was high in noncarbonate hardness and was from the same ditch supply used in Experiments 5, 6, and 7. Note that the count had increased from 25 c/m/5 ml to 56 c/m/5 ml. This was due to concentration by evaporation. It is interesting to compare results achieved in Experiment 16 in which no softening was accomplished with the results of Experiment 30 in which softening was achieved.

Experiments 17 through 30 were devoted to tests of a number of water-treating processes to develop data for comparison with results obtained earlier on reactor-produced fission products in the laboratory. Of interest is the solubility of the contaminant reported in Experiment 17. The dissolved fraction was 1.63 percent of the total radioactivity in the soil sample. This soil sample was obtained 30 yards from ground zero. Using a different technique, Robeck, Woodward, and Muschler¹ found the solubility of the contaminants in this soil to be approximately 10 percent. As noted earlier, the solubility of the contaminants collected at Station 9 was approximately 3.25 percent. No rational explanation is available for the wide range of indicated solubilities that have been reported in various studies, except when the soil and contaminants are fused as in the case of a low level or surface detonation. The tables showing the data from these experiments (17 through 30) will be of interest

1. Robeck, G. G., Woodward, R. L. and Muschler, W. K., A research Report on U. S. A. F. Project #7801, Robert Taft San Engrg Center, May 1958.

to other investigators, but they offer little need of further discussion at this time. In general, the results are consistent with earlier findings in the laboratory including the unexplained tendency for results to vary widely even under carefully controlled test conditions.

The measurement of radiostrontium levels in the soil and in the water samples was a source of much concern and irritation throughout this study. The magnitude of the levels reported appears high by at least an order of magnitude. The Nevada Test Site soil is high in calcium content, and other investigators have also reported considerable trouble in measurement of radiostrontium levels as low as those encountered in these experiments. In work at the Robert A. Taft Sanitary Engineering Center², it was found that strontium is preferentially dissolved by a factor of approximately 5. Although the experiments reported herein do not support direct comparison of findings, the consistently high radiostrontium levels as compared with radiocesium and the trivalent rare earths strongly suggest that radiostrontium was preferentially dissolved by a significant factor during these tests. A factor of 5 or even 50 would not be large in terms of absolute quantities of strontium in solution, but fractionation must be considered in evaluating tolerances for emergency water supplies, these being usually based on the gross level of contamination rather than on the amount of each radioisotope present.

In order to reduce to usable terms the findings of this and other prior studies, what can be expected on the atomic battlefield or at the site of a strategic target should be considered. It has been determined that nuclear weapons will contaminate the soil, the magnitude and extent of the contamination varying widely with the size and type of weapons and the methods of employment. Rain water falling on a contaminated area will become contaminated. In this study, it was demonstrated that a large portion of the radionuclides that are water soluble will go into solution relatively rapidly. This suggests that a large percentage of the soluble material will be carried off in the first heavy rainfall (or at least in the first several heavy rainfalls). Of the total radioactivity reaching surface drainage systems in normal runoff, a small fraction will be dissolved in the water; the larger fraction being present as suspended solids. Much of the suspended contaminant will be associated with clay and other materials. Some of the contaminant may exist in colloidal form. Where effective clarification equipment and procedures are available, this suspended material should not present a significant problem. In conventional surface water-treating plants, emphasis must be placed on effluent clarity. Control over chemical

2. Ibid.

coagulation, filter rates, and filter backwash cycles to meet a maximum effluent turbidity standard of 0.5 units would seem to be a reasonable and attainable goal. The presence of radioactive contaminants in surface waters will restrict the use of so-called emergency water treatment including the use of the Lister Bag. It is encouraging to note that the Water Purification Equipment, Knapsack Pack, 1/4 GPM, designed for squad use, is capable of removing essentially all suspended matter from water. Also of interest is the demonstration included in this project that ion exchange resins can be used by untrained personnel to decontaminate small quantities of water. The project officer is currently developing a device designed to treat and decontaminate water in quantities adequate to serve small fallout shelters.

In field water supplies produced from surface sources by the Corps of Engineers, the problem will be limited to the fraction of the contaminants in solution. The maximum amount of dissolved radioactivity to be experienced under combat conditions cannot be calculated from existing data. Of great importance is the field mobility of engineer water supply equipment which gives a wide range of choice with respect to sources. The contaminants of sanitary importance are, for the most part, $\text{Sr}^{89,90}$, Cs^{137} , and Ru^{106} . Radioactive iodine, $\text{Ce}^{141,144}$, and Ba^{140} may be of importance in some instances. Under the conditions of this study, from 1.63 to 3.25 percent of the contaminant in the soil was dissolved in the water. Unclassified data resulting from earlier work by USAERDL, under AFSW Project Jangle 6.8, showed that less than 0.1 percent of the contaminant was readily dissolved in water. In this instance, the bomb debris included considerable fused soil components and was recovered from near ground zero of a surface shot. The level of radiation at the site was above 150 R/hr at the time of the recovery and the experiment. In this instance, the contaminant was slurried in water and allowed to settle for a short period. The total radioactivity in the supernatant was approximately 0.5 percent of the total in the soil sample. Of this amount, 15.5 percent was dissolved. For estimating, it appears conservative to assume that 10 percent of the contaminant in the soil will be water soluble. Since the fraction in solution in a given sample is not directly related to the amount in suspension, it will not be possible to measure the total contamination in a turbid sample and estimate the fraction in solution. Water reconnaissance must provide for filtering a sample to permit measurement of the dissolved contaminant level.

The medical importance of the dissolved contaminant must be evaluated in terms of the characteristics of the radionuclides present, length of time the water must be used, and acceptable limits of human tolerances. It is to be emphasized that tolerances used in time of war must take into consideration the factor of

military necessity, and these tolerances will be higher than what is acceptable in peacetime civilian or military practice. Based on the available limited data, it does not appear that the dissolved radioactivity to be encountered under average battlefield conditions will exceed an acceptable level to be tolerated by combat troops under conditions of mobile operations offering opportunity for limiting the period of use of contaminated water. If this is true, the essential protection will be provided by removing all of the suspended contaminants. This is readily accomplished by routine operation of standard Corps of Engineers field water supply equipment. To meet the special situation, resort must be made to distillation, ion exchange, and other processes which remove all of the dissolved solids in the water.

Contaminated rain water entering the soil will normally come in contact with very large amounts of clay and other materials having some ion exchange or adsorptive capacity. Suspended materials are ordinarily filtered out as the water passes downward to the water table. It seems, therefore, that the probability of gross contamination of ground water is not great. For emergency planning, it seems reasonable to assume that ground water obtained from drilled and cased wells will not quickly become contaminated by either suspended or dissolved radionuclides even in areas of very heavy surface contamination. This offers a unique solution to the water supply problem of deep shelters since wells can be developed within the confines of the shelter, eliminating all requirements for above-ground facilities or underground storage tanks. Ground water from deep wells should be considered as the primary solution wherever possible. This applies even when the available ground water supply is so limited that contaminated surface water must be used for all other purposes except drinking and cooking. This suggests that a nation-wide survey of existing wells and plans for their use in an emergency would be a productive program for those responsible for the civil defense.

This is not to infer that ground water will be immune to contamination. The literature is essentially silent in this regard, but recent studies on the transport of syndets and other domestic and industrial waste products by ground water strongly suggest that ground water would, in time, bear its proportionate burden of the contaminants falling out on the ground surface. Again, the problem would be that fraction that is water soluble.

8. Future Studies. The statements in the paragraphs immediately preceding are based on limited data and are not confined to the results achieved during this study. While they provide an interim basis for planning, need exists for continuing effort to expand the data and to permit reevaluation of the assumptions made. It is clear,

therefore, that water solubility and related studies must be continued. Work done under Project 50.4 suggests that further work can be achieved in the contaminant areas of the Nevada Test Site without any direct relationship to weapons testing programs. Such studies should provide for tests using soils other than that indigenous to the Nevada Test Site and test procedures more closely approximating the action of rainfall on contaminated soil. A realistic program should include some basic work leading to a better understanding of ground water contamination. In addition to the Nevada Test Site, facilities exist at ORNL and at USAERDL for the conduct and/or support of such studies. Further development of laboratory procedures tailored to meet the requirements of water analysis is also indicated.

The potential problem of alpha contamination of water is not discussed elsewhere. Unfissioned bomb material or reactor fuels could be of importance, particularly in the event of accidents. Tolerance of these contaminants is extremely low. Review of the technical literature shows that little is known concerning these materials as water contaminants. In view of the dearth of data and the ever present possibility of a contaminating accident even in peacetime, this problem demands early attention. Facilities for conducting the laboratory portion of such studies exist at the AEC installation at Los Alamos, New Mexico; a series of experiments evaluating Corps of Engineers water supply equipment and processes for removing the plutonium ion from water is scheduled for February-March-April 1959.

The conduct of work under Project 50.4 by the USAERDL with the support and cooperation of the United States Continental Army Command, the Robert A. Taft Sanitary Engineering Center, HEW; ORNL, AEC; and the Office of Civil and Defense Mobilization points the way for additional productive work in this technical area. All necessary coordination was accomplished by the Project Officer under authority granted by the Director, USAERDL. Direct technical liaison was maintained between the interested agencies, and each contributed support as available and shared in the results achieved. In view of the broad interest existing in the general problem area of radioactive contamination, the relatively high cost of research in this area, and the ever present need for economy of operations in the Federal Government, this pattern of research operations appears to deserve continuing consideration.

IV. FINDINGS

9. Findings. It was found that:

a. The radioactive debris resulting from a nuclear detonation was only sparingly soluble in water. The water soluble component dissolved quickly, with but limited additional solution taking place as a result of further agitation and contact time. Increasing the dosage of contaminated soil resulted in a higher concentration of activity in solution. Leaching the same sample a second time resulted in a solution containing less than one half the activity in the first leach.

b. The solubility of the radioactive debris increased as the pH of the solvent was lowered.

c. Filtration through dense filter pads or through bonded ceramic elements effectively removed suspended radioactive debris from water. Such filtration followed by demineralization with a column of mixed bed ion exchange resins removed both suspended and dissolved contaminants.

d. Coagulation followed by filtration was effective in removing suspended contaminants from water but was relatively ineffective in removing the dissolved components of the radioactive debris.

e. Lime and lime-soda softening were relatively ineffective in removing the dissolved components of radioactive debris from water.

f. Clay was not effective in removing the dissolved contaminants from water although earlier research had indicated that significant removals of many radioisotopes can be thus achieved.

g. Coagulation followed by filtration followed by demineralization by ion exchange resins removed all of the contaminants, suspended and dissolved components alike.

V. CONCLUSIONS

10. Conclusions The report concludes that:

a. Radioactive debris resulting from a normal nuclear detonation is only sparingly soluble in water in the pH range of natural surface waters.

b. Where effective clarification procedures are used, only the dissolved radioactive contaminants will be of importance to those charged with responsibility for the safety of potable water systems.

c. To accomplish complete decontamination, normal water-treating (clarification) processes must be supplemented by distillation, ion exchange, or other processes which remove essentially all dissolved solids from water.

d. The work conducted under Project 50.4 has significantly extended the knowledge concerning water contamination resulting from nuclear bomb debris. However, this work and related studies should be continued and expanded.

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APPENDICES

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APPENDIX A

AUTHORITY

Subproject of project 8-75-07-200

R & D PROJECT CARD		TYPE OF REPORT	REPORT CONTROL SYMBOL
1. PROJECT TITLE REMOVAL OF CBR CONTAMINANTS FROM WATER		PROGRESS	CSCRD-1
2. SECURITY OF PROJECT U		3. PROJECT NO. 8-75-07-214	4. JPRS NUMBER 2098/239
5. BASIC FIELD OR SUBJECT Water Supply		6. REPORT DATE 31 Dec 1957	7A. TECH. ORG. SO-9
8. COGNIZANT AGENCY C of E	9. DIRECTING AGENCY Engr Res & Dev Div, TO, OCE	10. REQUESTING AGENCY OCE	11. CONTRACTOR AND/OR LABORATORY Engr Res & Dev Lab Infilco, Inc.
12. PARTICIPATION AND/OR COORDINATION Chemical Corps (P) (Facilities) (Technical Personnel) (Equipment) (Project No. 4-75-05-001)		13. RELATED PROJECTS	
14. DATE APPROVED 5 Dec 52, by GSUSA		15. PRIORITY	
16. MAJOR CATEGORY		17. EST. COMPLETION DATES RES. Continuing DEV. TEST OP. EVAL.	
18. FY.		19. FISCAL ESTIMATES	
20. REPLACED PROJECT CARD AND PROJECT STATUS Supersedes Project Card dated 31 Dec 55. Downgraded Unclassified by CETC 2240/275.			
21. EQUIPMENT AND/OR JUSTIFICATION There is a requirement for determination of the effectiveness of Army field water purification equipment and processes now standard and under development for removing chemical, biological, and radioactive agents from water to be used for drinking and other purposes. This requirement has been established by the threat of new and more efficient agents and weapons of war.			
22. BRIEF OF PROJECT AND OBJECTIVE a. Brief: (1) Objective: (a) Determination of the capabilities and limitations of Army field water supply equipment and water treatment processes now standard or under development with respect to purifying water containing chemical, biological, and radioactive contaminants, as determined by the Chemical Corps and other agencies. (b) Establishment, where necessary, of new water treatment techniques, on the basis of coordinated information from Chemical Corps, for the removal of these contaminants from water.			
23. OASD (R & D)	24. SN	25. CH	26. C.
DD FORM 1 APR 55 613		PAGE 1 OF 3 PAGES	
REPLACES DD FORM 613 1 JAN 52.			

R&D PROJECT CARD
CONTINUATION SHEET

SQ-9

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NO.
REMOVAL OF CBH CONTAMINANTS FROM WATER	II	R-75-07-214
	C of E	1. REPORT DATE 31 Dec 1957

Block 21a continued

(2) Military Characteristics:

There are no military characteristics applicable to this project. Should design changes in equipment be required, the work will be accomplished under this project.

b. Approach:

- (1) The studies and tests to be conducted under this project with respect to radioactive contaminants will be accomplished under arrangements already existing between the Corps of Engineers, the Chemical Corps, and the Atomic Energy Commission in connection with superseded project 8-75-05-008. Activities in this field will be conducted by the Corps of Engineers detachment at ORNL, Oak Ridge, Tennessee. All contaminants will be procured from ORNL, and technical assistance of ORNL specialists will be obtained when necessary.
- (2) This project will be conducted on full size field serviceable equipment. The ORNL representative equipment and processes will be evaluated using both mixed fission products and potential CW contaminants. To reduce the possibility of errors and to demonstrate associated problems, dosages of contaminants used will be the largest dosages expected under combat conditions. Should the data show that these dosages cannot be effectively handled, then the limit of effectiveness of the equipment or processes will be established. The same general concept will apply to the studies of chemical and biological agents. In the case of biological agents, the potential hazard involved dictates that simulated agents (non-pathogenic organisms) be used in many tests.
- (3) All studies and tests to be conducted using biological and chemical contaminants will be carefully coordinated and accomplished with the participation of the Chemical Corps. All contaminants will be furnished by the Chemical Corps, together with special personnel required to safely handle the contaminants and to conduct special analyses. All equipment to be tested will be furnished by the Corps of Engineers. Tests will be conducted at Chemical Corps installations such as Fort Detrick, Frederick, Md.; Chemical Corps Medical Laboratories, Army Chemical Center, Md.; and such other installations as may be designated, and at the Engineer Research and Development Laboratories, as dictated by the requirements of the individual test.
- (4) Where chemical, biological, and radiological agents are being studied, all necessary safety precautions will be used.
- (5) Report will be submitted covering each major grouping of contaminants used. A final project report will be submitted which will emphasize the field application of the information resulting from this project. While tests on the several contaminants may be carried out simultaneously, the general order of work will be to consider radioactive, chemical, and biological agents in turn.

R&D PROJECT CARD
CONTINUATION SHEET

80-9

1. PROJECT TITLE REMOVAL OF CBR CONTAMINANTS FROM WATER	2. SECURITY OF PROJECT U C of E	3. PROJECT NO. 8-75-07-214 4. REPORT DATE 31 Dec 1947
<p>Block 21 continued.</p> <p>c. Subtasks: Techniques for handling chemical and biological contaminants and the disposal of wastes must be developed. These problems are not considered insurmountable and will be resolved by qualified personnel of the Chemical Corps.</p> <p>d. Other Information:</p> <p>(1) References: Requirement for equipment and methods for decontaminating water is contained in the Army Equipment Development Guide, paragraph 217.</p> <p>(2) Discussion:</p> <p>(a) The potential problems associated with chemical, biological, and radioactive contaminants with respect to field water supplies have been greatly increased in recent years by marked advances in the development of contaminants and weapons. Corps of Engineers Project 8-75-05-008, "Wahoo," provided for a basic study and evaluation of the problems of removing AW and RW contaminants from water. Significant data have been developed under project "Wahoo". These data have shown that standard field water purification equipment with the use of additional supplies in the coagulation phases of the water purification process is effective in meeting minimum standards established for radioactive contamination tolerances in drinking water. Procedures with respect thereto are being prepared at this time. This project is intended to supersede Project 8-75-05-008, "Wahoo," but will not duplicate work already done under the former project. It is expected that the project will result not only in establishing the capabilities and limitations of equipment and methods but will provide data to guide personnel training procedures. It is to be noted that the military importance of many potentially excellent contaminants is reduced by the inability of the user to protect friendly forces. It is possible, therefore, that the work under this project, through development of protective measures with respect to water, may bring into sharp focus the offensive capabilities of agents which today are not suitable for combat use.</p> <p>(b) Agencies interested in this project, in addition to the Corps of Engineers, with which liaison will be maintained and which will be furnished copies of the reports on the project, are the Department of the Navy, Department of the Air Force, Chemical Corps, Army Medical Service, CONARC.</p> <p>(c) Reports resulting from work at ORNL will be made available to the Atomic Energy Commission.</p>		
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APPENDIX B

EXPERIMENT DATA

EXPERIMENT 3 COAGULATION OF TURBID WATER FROM WATER PAN AT STATION 8

DATE: 28 June 1957

OBJECTIVE: To determine the removal of activity from turbid water at station 8 by coagulation with ferric chloride and limestone in various doses.

CONTAMINATED WATER: Turbid water from water pan at Station 8 after shot Priscilla.

ANALYSIS OF CONTAMINATED WATER: Alkalinity (centrifuged) 521 ppm, pH 7.7, activity uncentrifuged 2640 c/m/5ml, and activity centrifuged 940 c/m/5ml.

PROCEDURE:

1. Add 600 ml turbid water to each beaker.
2. Add coagulants.
3. Rapid mix 5 mins.
4. Slow mix 15 mins.
5. Settle 20 mins.
6. Centrifuge and analyze for alkalinity, pH, and activity.

Beaker	FeCl ₃ (ppm)	CaCO ₃ (ppm)	After Coagulation and Centrifugation			Activity Removal	
			Alkalinity (ppm)	pH	Activity (c/m/5ml)	Turbidity (%)	Overall (%)
1	25	50	280	7.5	790	100 (assumed)	70
2	50	75	460	7.5	800	"	70
3	75	100	280	7.3	775	"	71
4	100	125	300	7.5	755	"	71
5	125	150	280	7.6	685	"	74
6	150	175	270	6.8	660	"	75

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EXPERIMENT 4
REMOVAL OF ACTIVITY WITH "WATER PURIFICATION UNIT, HAND-OPERATED,
KNAPSACK-PACK, FILTER-PAD-TYPE, 1/4 GPM" (SET NO. 1)

DATE: 28 June 1957

OBJECTIVE: To determine the removal of activity from contaminated water by two separate processes: (1) filtration through set No. 1 followed by demineralization in an MB-3 ion exchange column, and (2) coagulation with ferric chloride and limestone, followed by centrifugation and demineralization with MB-3 in an ion exchange column.

CONTAMINATED WATER: Prepared from radioactive debris taken as a composite from the fallout pans at station 9. The composite was slurried in water in a bucket and allowed to settle for a brief period. The supernatant liquid (2200 ppm turbidity) was then transferred to tap water in a clean garbage can and agitated. The resulting water was then submitted to the two processes mentioned in OBJECTIVE.

ANALYSIS OF CONTAMINATED WATER: Activity unfiltered 215 c/m/5ml.

PROCEDURE:

1. Filtration and ion exchange.
 - a. Filter thru set No. 1.
 - b. Pass filtrate through ion exchange column filled with MB-3.
2. Coagulation and ion exchange.
 - a. Coagulate with ferric chloride and limestone.
 - b. Centrifuge.
 - c. Pass centrifugate through ion exchange column filled with MB-3.

TREATMENT	PROCEDURE	ACTIVITY (c/m/5ml)	CUMULATIVE Activity Removal (%)
1	Raw Water After Filtration Thru Set 1 After MB-3 Ion Exchange	215 7 0	- 97 100
2	Raw Water After Coagulation After Centrifuging After MB-3 Ion Exchange	215 18 0.9 0.3	- 92 99.6 99.9

RADIOCHEMICAL DATA

RADIOELEMENT	INFLUENT TO SET 1 (c/m/5ml)	EFFLUENT FROM SET 1 (c/m/5ml)	REMOVAL (%)
Gross Beta	200	133	60
Radiocesium	65	0	100
Radiostrotrium	40	5	88
Trivalent rare earths (Plus yttrium)	150	55	73

NOTE: 1. No detectable alpha or gamma activity
2. Analysis 13 July 1957, by Analytical Chemistry Division, ORNL

EXPERIMENT 5
COAGULATION OF DITCH WATER FROM FRENCHMAN FLAT

DATE: 1 July 1957

OBJECTIVE: To determine the removal of activity from Frenchman Flat ditch water by coagulation with ferric chloride and limestone in various dosages.

CONTAMINATED WATER: Ditch water from Frenchman Flat after shot FRISCHILLA.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 90 ppm, hardness 340 ppm, pH 7.9, and activity 25 c/m/5ml.

PROCEDURE:

1. Add 500 ml ditch water to each beaker.
2. Add coagulants.
3. Rapid mix 5 mins.
4. Slow mix 15 mins.
5. Settle 30 mins.
6. Filter thru membrane filter.
7. Analyze for alkalinity, pH, and activity.

Beaker	FeCl ₃ (ppm)	CaSO ₄ (ppt)	Floc Formation	After Coagulation and Filtration		
				Alkalinity (ppm)	pH	Activity (c/m/5ml)
1	25	50	Excellent	56	7.9	-
2	50	75	Good	50	7.4	23
3	75	100	Good	42	7.3	16
4	100	125	Average	42	7.1	17
5	125	150	Passing	38	7.1	16
6	150	175	Passing	38	6.9	19
						24

EXPERIMENT 6
DECONTAMINATION OF FRENCHMAN FLAT DITCH WATER BY
COAGULATION, FILTRATION, AND ION EXCHANGE

DATE: 3 July 1957

OBJECTIVE: To determine the removal of activity from Frenchman Flat ditch water by coagulation, filtration, and ion exchange.

CONTAMINATED WATER: Ditch water from Frenchman Flat after shot PRISCILLA.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 110 ppm, pH 8.0, turbidity 30 ppm, and activity (unfiltered and filtered) 23 c/m/5ml.

PROCEDURE:

1. Add 600 ml ditch water to each beaker.
2. Slurry water in beakers 7 and 8 with 1000 ppm of local clay for 20 mins.
3. Add coagulants to all beakers.
4. Rapid mix 5 mins at 216 rpm.
5. Slow mix 15 mins at 36 rpm.
6. Settle 20 mins.
7. Filter thru membrane filter.
8. Analyze for alkalinity, pH, and activity.
9. Pass filtrate through cation exchange resin (Dowex 50-x8).
10. Analyze for activity.
11. Pass through anion exchange resin (Dowex 2-x 7.5).
12. Analyze for activity.

Beaker	Clay (ppm)	FeCl ₃ (ppm)	CaCO ₃ (ppm)	After Coagulation and MF Filtration			Activity After Cation Exchanger (c/m/5ml)	Activity After Anion Exchanger (c/m/5ml)	Activity Removal By Coagulation (%)	Overall Activity Removal (%)
				Alkalinity (ppm)	pH	Activity (c/m/5ml)				
1	0	25	50	60	7.9	20	8	0	13	100
2	0	50	75	60	7.6	21	10	0	9	100
3	0	75	100	58	7.5	15	8	0	35	100
4	0	100	125	56	7.5	18	8	0	22	100
5	0	125	150	50	7.4	10	8	0	57	100
6	0	150	175	46	7.3	15	-	0	35	100
7	1000	125	150	44	7.2	18	17	0	22	100
8	1000	150	175	-	-	21	8	0	9	100

RADIOCHEMICAL DATA (Sample Beaker 5, Coagulated, Filtered)

RADIOELEMENT	%
Radiocesium	5
Radiocstrontium	15
Trivalent rare earths (including yttrium)	7
Other	73

EXPERIMENT 7
FIELD WATER DECONTAMINATION EXPERIMENT USING THE KATADYN
FILTERPURE UNIT FOLLOWED BY THE LAMOTTE FILTER-ION UNIT

DATE: 3 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by filtration through a Katadyn FILTERPURE unit followed by demineralization with the Lamotte FILTER-ION unit.

CONTAMINATED WATER: Ditch water on Frenchman Flat.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 200 ppm, pH 7.9, and turbidity 12 ppm.

PROCEDURE:

1. Perform experiment in the field (East bank ditch 250 yards from ground zero-radiation reading at time of experiment, 30 mr/hr measured 1 ft above ground).
2. Filter water from ditch through Katadyn FILTERPURE unit.
3. Analyze for alkalinity, pH, and turbidity.
4. Beginning with the third 250 ml volume, pass the filtrate through the Lamotte FILTER-ION unit.
5. Analyze for alkalinity, pH, and turbidity.

SAMPLE	ALKALINITY (ppm)	pH	TURBIDITY (ppm)
Raw Water	200	7.9	12.
After Katadyn Unit	205	7.9	0.5
After Katadyn Unit and Filtration Unit	10	7.5	0.1

RADIOCHEMICAL DATA

RADIOELEMENT	RAW WATER FOR KATADYN UNIT (%)	FILTERED WATER FROM KATADYN UNIT (%)
Radiocesium	15	5
Radiostrotrontium	21	22
Trivalent rare earths (including yttrium)	13	5
Other	51	68

EXPERIMENT 8
EFFECT OF AGITATION ON SOLUBILITY OF RADIOACTIVE DEBRIS
IN TAP WATER

DATE: 4 July 1957

OBJECTIVE: To determine the effect of agitation on the solubility of radioactive debris in tap water at a concentration of 10,000 ppc.

CONTAMINANT: Radioactive debris collected 3 July 1957, 50 yards NE from ground zero (see experiment 10 for analysis).

ANALYSIS OF TAP WATER: Alkalinity 200 ppm, pH 8.3.

PROCEDURE:

1. Add 6 grams debris to each beaker.
2. Add 600 ml tap water to each beaker.
3. Agitate for desired length of time at 28 rpm.
4. Filter through Whatman 54 filter paper.
5. Analyze for alkalinity, pH, and activity.

Beaker	Agitation Time (min)	After Agitation and Filtration	
		Alkalinity (ppm)	pH Activity (c/m/5ml)
1	1	222	7.8 24
2	2	218	7.8 24
3	5	220	7.8 31
4	10	220	7.8 32
5	30	210	7.7 41
6	60	204	7.8 31
7	120	220	7.8 71
8	240	208	7.8 48

EXPERIMENT 9
EFFECT OF AGITATION ON SOLUBILITY OF RADIOACTIVE DERRIS
IN DISTILLED WATER

DATE: 5 July 1957

OBJECTIVE: To determine the effect of agitation on the solubility of radioactive debris in distilled water at a concentration of 10,000 ppm.

CONTAMINANT: Radioactive debris collected 3 July 1957, 50 yards NE from ground zero (see experiment 10 for analysis).

PROCEDURE:

1. Add 6 grams debris to each beaker.
2. Add 600 ml distilled water to each beaker.
3. Agitate for desired length of time at 28 rpm.
4. Filter through Whatman 54 filter paper.
5. Analyze for alkalinity, pH, and activity.

Beaker	Agitation Time (min)	After Agitation and Filtration		
		Alkalinity (ppm)	pH	Activity (c/m/5ml)
1	1	35	8.3	35
2	2	40	8.3	35
3	5	40	8.4	35
4	10	45	8.5	41
5	30	50	8.5	43
6	60	55	8.5	54
7	120	75	8.4	68
8	240	70	8.4	51

RADIOCHEMICAL DATA (Filtered Water from Beaker 7)

RADIOELEMENT	ϕ
Radiocesium	2
Radiostrontium	28
Trivalent rare earths (including yttrium)	44
Other	26

EXPERIMENT 10
EFFECT OF pH ON SOLUBILITY OF RADIOACTIVE DEBRIS
IN DISTILLED WATER

DATE: 8 July 1957

OBJECTIVE: To determine the effect of pH on the solubility of radioactive debris in distilled water at a constant concentration of 10,000 ppm.

CONTAMINANT: Two contaminants were used for this experiment, (1) radioactive debris collected 3 July 1957, 50 yards NE from ground zero (analyzing 8086 counts per minute per gram), and (2) composite of fallout pan debris from Station 9 and debris from Station 8 which had been sized to greater than 50 microns (analyzing 1275 counts per minute per gram).

PROCEDURE:

1. Add 6 grams debris or fallout to each beaker.
2. Add 600 ml distilled water to each beaker.
3. Adjust pH to desired value with either 6M hydrochloric acid or 1M sodium hydroxide solution.
4. Agitate 120 mins at 28 rpm.
5. Filter through Whatman 54 filter paper.
6. Filter samples from beakers 1-5 through membrane filter in addition to Whatman 54.
7. Analyze for alkalinity, pH, and activity.

Beaker	Contaminant	After Agitation and Filtration			Count 18 hrs later		
		Alkalinity (ppm)	pH	Activity (c/m/5ml)	After Membrane Filter (c/m/5ml)	Whatman Filtration (c/m/5ml)	Membrane Filtration (c/m/5ml)
1	1	Negative	3.2	205	134	187	171
2	1	120	6.5	84	66	74	72
3	1	90	7.3	66	42	53	43
4	1	90	8.7	59	22	53	26
5	1	390	10.4	70	25	62	24
6	2	75	5.6	14			
7	2	160	6.8	8			
8	2	110	7.5	3			
9	2	160	9.1	6			
10	2	400	10.3	1			

NOTE: Beaker 1 was neutralized to pH 7 and filtered through a membrane filter.
The resulting count was 147 c/m/5ml (141 c/m/5ml 18 hours later).

RADIOCHEMICAL DATA

RADIOELEMENT	After Filtration Through Membrane Filter		
	Beaker 2 (%)	Beaker 3 (%)	Beaker 5 (%)
Radiocesium	15	5	10
Radiostrotrontium	24	31	40
Trivalent rare earths (including yttrium)	43	26	10
Other	18	39	40

DECAY DATA ON RADIOACTIVE DEBRIS USED IN EXPERIMENT 8

DAYS FOLLOWING EXPERIMENT	DEBRIS 1 (c/p/gram)		DEBRIS 2 (c/p/gram)	
0	8086		1275	
2	7118		1241	
4	6213		960	
5	5864		5373	
7	582		972	

EXPERIMENT 11
EFFECT OF CONCENTRATION ON THE SOLUBILITY OF
RADIOACTIVE DEBRIS IN DISTILLED WATER

DATE: 9 July 1957

OBJECTIVE: To determine the effect of concentration (in the range 100 ppm to 100,000 ppm) on the solubility of radioactive debris in distilled water at a constant degree of agitation

CONTAMINANT: Radioactive debris collected 3 July 1957, 50 yards NE from ground zero (see experiment 10 for analysis).

PROCEDURE:

1. Add desired amount of debris to each beaker.
2. Add 600 ml distilled water to each beaker.
3. Agitate for 120 mins at 28 rpm.
4. Filter through Whatman #4 filter paper.
5. Analyze for alkalinity, pH, and activity.

Beaker	Debris Concentration (ppm)	After Agitation and Filtration		
		Alkalinity (ppm)	pH	Activity (c/m/5ml)
1	100	18	3.1	4
2	500	26	8.5	4
3	1000	25	8.5	3
4	5000	30	8.5	19
5	10000	30	8.4	27
6	50000	36	8.3	87
7	100000	13	8.2	129

RADIOCHEMICAL DATA

RADIO ELEMENT	FILTERED WATER		
	Beaker 5 12 July 57	Beaker 6 12 July 57	Beaker 7 1 Oct 57
Radiocesium	41%	50%	49%
Radiostrotrontium	-	-	9%
Trivalent rare earths (including yttrium)	-	-	21%
Other	59%	50%	51%
Total beta count (c/m/5ml)	27	87	129
			31

EXPERIMENT 12 WATER LEACHING OF RADIOACTIVE DEBRIS

DATE: 10 July 1957

OBJECTIVE: To determine the quantity of radioactivity that can be leached with distilled water.
CONTAMINANT: Radioactive debris collected 3 July 1957, 50 yards NE from ground zero (see experiment 10 for analysis).

PROCEDURE:

1. Add 300 grams of debris to a one gallon jug at 0930, 10 July 1957.
2. Add three liters of distilled water and invert 5 times.
3. Sample periodically for pH and activity.
4. Invert 5 times after each sampling.

Leaching Time (hrs)	pH	Activity of Supernatant (c/m/5ml)	Activity of Filtered Supernatant (c/m/5ml)
1	8.4	789	130 (MF)
3 1/2 *	8.4	459	127 "
24	8.2	165	117 "
48	8.2	168	154 "
72	8.2	156	147 "
125	7.8	152	132 Whatman 42
219	7.9	86	60 "
2739	9.2	22	22 "

* Time between samples.

RADIOCHEMICAL DATA

RADIO ELEMENT	FILTERED SUPERNATANT	
	24 Hour Leach 12 July 57	24 Hour Leach 1 Oct 57
Radiocesium	25%	45%
Radiostrontium	-	12%
Trivalent rare earths (including yttrium)	-	39%
Other	75%	4%
Total beta count (c/m/5ml)	117	45

DECAY DATA

SAMPLE	ACTIVITY (C/M/5ML)		
	11 July 57	12 July 57	13 July 57
1 Hour Supernatant	708	683	632
1 " MF	111		105
1 " Supernatant	447	414	379
3 " MF	122	113	106
3 " Supernatant		170	160
24 " MF		113	114
24 " MF			596
			97

EXPERIMENT 13
ACIDULATION AND NEUTRALIZATION OF RADIOACTIVE DERRIS

DATE: 11 July 1957

OBJECTIVE: To determine the effect of acidulation and neutralization on the amount of activity removed by water from radioactive debris.

CONTAMINANT: Radioactive debris collected 3 July 1957, 50 yards northeast from ground zero (see experiment 10 for analysis).

PROCEDURE:

1. Add 6 grams debris to each beaker.
2. Add 600 ml distilled water to each beaker.
3. Lower pH to 2.8 with hydrochloric acid (series 1) or nitric acid (series 2).
4. Agitate 60 mins at 28 rpm.
5. Elevate pH with various amounts of sodium hydroxide solution.
6. Filter through Whatman 54 filter paper.
7. Analyze for pH and activity.

Beaker	Acid Used	Precipitate After Addition of Caustic	After Filtration	
			pH	Activity (c/m/ml)
1	HCl		3.1	190
2	"	Slight PPT.	6.2	148
3	"	No Apparent PPT.	8.3	146
4	"	PPT.	9.7	116
5	"	PPT.	10.5	70
6	HNO ₃		3.0	236
7	"	Slight PPT.	5.7	166
8	"	Very Slight PPT.	7.9	147
9	"	PPT.	9.4	121
10	"	PPT.	10.3	75

EXPERIMENT 14
SOLUBILITY OF RADIOACTIVE DEBRIS AS A FUNCTION OF PARTICLE SIZE

DATE: 12 July 1957

OBJECTIVE: To determine the solubility of radioactive debris in water as a function of particle size.

CONTAMINANT: Radioactive debris collected from Frenchman Flat and sized to 3 size fractions.

PROCEDURE:

1. Add desired amount of debris to each beaker.
2. Add 600 ml distilled water to each beaker.
3. Agitate 60 mins at 28 rpm.
4. Filter through Whatman 42 filter paper.
5. Analyze for pH and activity.

Beaker	Contaminant	Concentration (ppm)	After Filtration	
			pH	(c/m/5ml)
1	1 -	50 μ	9.0	19
2	1 -	50 μ	8.6	131
3	2 -	50 μ	9.2	7
4	2 -	50 μ	8.9	70
5	Composite	5- 50 μ	8.7	30
6	"	5- 50 μ	8.6	185
7	"	< 5 μ	8.6	85
8	"	< 5 μ	8.4	143

EXPERIMENT 15
REMOVAL OF RADIOACTIVITY FROM WATER WITH A POLYELECTROLYTE

DATE: 12 July 1957

OBJECTIVE: To determine the removal of radioactivity from contaminated water by coagulation with a polyelectrolyte.

CONTAMINATED WATER: Liquid slurry samples from experiment 14.

PROCEDURE:

1. Agitate 30 mins at 28 rpm.
2. Remove an unfiltered sample from each beaker and check for activity.
3. Add quantity of polyelectrolyte (Dow Separan 2610) to each beaker to give a concentration of 25 ppm.
4. Agitate 7 mins.
5. Settle 60 mins.
6. Analyze for activity.

Beaker	Activity of Unfiltered Water (c/m/5ml)	Activity After Separan 2610 and Settling (c/m/5ml)
1	72	51
2	904	166
3	34	16
4	186	102
5	215	98
6	1359	211
7	455	157
8	2066	165

EXPERIMENT 16
SOFTENING OF FRENCHMAN FLAT DITCH WATER WITH LIME

DATE: 13 July 1957

OBJECTIVE: To determine the removal of activity in Frenchman Flat ditch water by softening with lime.

CONTAMINATED WATER: Ditch water from Frenchman Flat

ANALYSIS OF CONTAMINATED WATER: Alkalinity 107 ppc, hardness 374 ppm, pH 7.9, activity 56 c/m/5ml

PROCEDURE:

1. Add 600 ml ditch water to each beaker.
2. Add lime.
3. Rapid mix 5 mins at 144 rpm.
4. Slow mix 20 mins at 28 rpm.
5. Settle 30 mins.
6. Filter through Whatman 42 filter paper
7. Analyze for alkalinity, hardness, and pH, and activity.

Beaker	Lime (ppm)	After Softening and Whatman 42 Filtration			Activity Removal (%)
		Alkalinity (ppm)	pH	Hardness (ppc)	
1	103	384	9.9	490	25
2	137	244	10.0	496	20
3	171	252	10.0	540	13
4	205	282	10.2	601	20
5	239	292	10.2	564	13

This experiment was an initial trial. No reduction in hardness was accomplished.

EXPERIMENT 17
COAGULATION OF CONTAMINATED WATER WITH FERRIC CHLORIDE
AND WITH POTASSIUM ALUM

DATE: 15 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation with ferric chloride and with potassium alum.

CONTAMINATED WATER: The contaminated water used for experiments 17-27 incl. was prepared by taking 208 lbs of soil collected 30 yards northeast of ground zero and agitating it for 1 1/2 hours with 250 gallons of tap water in a 500 gallon tank. The water was then settled. Prior to slurring, the soil was analyzed for gross count by weighing samples from 0.02 to 1 gram, counting, and extrapolating to zero weight. The count extrapolated to zero weight was 13,000 counts per minute per gram. With the supernatant reading 107 c/m/5ml (filtered, and at 5.6% geometry), a solubility of 1.63% is indicated. The supernatant was also submitted to a radiochemical analysis 2 1/2 months later, when the radioactive component analyzed 43% radocesium, 15% radiostrontium, and 24% trivalent rare earths. The supernatant was also checked for gross activity at 10% geometry, including alpha, beta, and gamma count; the results being 0.1 c/m/5ml alpha, 9 c/m/5ml beta, and 10 c/m/5ml gamma.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 140 ppm, total hardness 253 ppm, magnesium hardness 126 ppm, pH 7.3, turbidity 40 ppm, activity unfiltered 117 c/m/5ml, and activity filtered 107 c/m/5ml.

PROCEDURE:

1. Add 100 ml contaminated water to each beaker.
2. Add coagulant.
3. Rapid mix 5 mins at 144 rpm.
4. Rapid mix 15 mins at 28 rpm.
5. Settle 30 mins.
6. Filter through Whatman filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	Coagulant	Dosage (ppm)	After Coagulation and Filtration					Dissolved		Overall
			Alka- linity (ppm)	pH	Calcium Hardness (ppm)	Magnesium Hardness (ppm)	Total Hardness (ppm)	Activity Removal (%)	Activity Removal (%)	
1	FeCl ₃	20	130	6.9	120	100	220	74	31	37
2	"	40	120	6.8	120	100	220	64	38	43
3	"	60	90	6.4	110	150	260	60	44	49
4	"	80	70	6.3	130	130	260	74	31	37
5	"	100	50	6.0	130	130	260	53	46	50
6	Al ₂ (SO ₄) ₃	30	170	7.0	130	120	250	103	4	12
7	K ₂ SO ₄	60	140	7.2	240	90	330	100	7	15
8	"	90	120	7.1	140	140	280	100	7	15
9	"	120	110	6.8	150	120	270	91	15	22
10	"	150	100	6.7	170	110	280	80	25	32

DEJAY DATA ON SOIL (30 yards northeast GZ) and
SUPERNATANT LIQUID USED IN EXPERIMENTS 17 - 27

Sample	15 July	16 July	17 July	18 July	19 July
1. Gram Soil 30 Yards Northeast GZ (c/m/gram)	5621	5407	2473	2336	2289
Unfiltered Supernatant (c/m/5ml)	127	108	59	58	54
Filtered Supernatant (c/m/5ml)	107	101	49	47	53

NOTE: Tracerlab GM tube used for counting 15, 16 July.
Nuclear-Chicago GM tube used for counting 17, 18, 19 July

EXPERIMENT 18
COAGULATION OF CONTAMINATED WATER WITH HIGH DOSAGES OF FERRIC CHLORIDE

DATE: 16 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation with high dosages of ferric chloride.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs. of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 140 ppm, total hardness 230 ppm, pH 7.6, turbidity 50 ppm, activity unfiltered 70 c/m/5ml, and activity filtered 67 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add coagulant.
3. Rapid mix 5 min at 115 rpm.
4. Slow mix 15 min at 28 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	FeCl ₃ (ppm)	After Coagulation and Filtration			Dissolved Activity Removal (%)	Overall Activity Removal (%)
		Alkalinity (ppm)	pH	Total Hardness (ppm) (c/m/5ml)		
1	100	75	6.1	220	36	39
2	125	60	6.0	220	25	29
3	150	50	5.9	220	48	50
4	175	30	5.7	220	54	56
5	200	20	5.5	220	54	56

RADIOCHEMICAL DATA (Filtrate Beaker 5, 1 Oct 57)

RADIO ELEMENT	(%) *
Radiocesium	50
Radiostrontium	11
Trivalent rare earths (including yttrium)	49
Other	0
Total beta count (c/m/5cl)	23

* Sum of percentages total 110%. Reflects difficulty of radiochemical analyses involving small amounts of radioactivity.

EXPERIMENT 19
COAGULATION OF CONTAMINATED WATER WITH FERRIC CHLORIDE
AND SODIUM CARBONATE (At constant alkalinity)

DATE: 16 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation with ferric chloride and sodium carbonate; at constant alkalinity.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 140 ppm, total hardness 230 ppm, pH 7.6, turbidity 50 ppm, activity unfiltered 70 c/m/5ml, and activity filtered 67 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add coagulants.
3. Rapid mix 5 min at 115 rpm.
4. Slow mix 15 min at 28 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	FeCl ₃ (ppm)	Na ₂ CO ₃ (ppm)	After Coagulation and Filtration			Dissolved Activity Removal (%)	Overall Activity Removal (%)
			Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity (c/m/5ml)	
1	20	16	145	7.4	220	58	17
2	40	32	173	7.3	230	49	30
3	60	48	140	7.2	220	46	34
4	80	64	140	7.1	230	48	31
5	100	80	156	7.0	225	41	41
6	125	100	140	6.9	210	36	49
7	150	120	164	6.8	210	37	47
8	175	140	159	6.7	205	36	49
9	200	160	164	6.6	200	29	44

RADIOCHEMICAL DATA (Filtrate Beaker 6, 1 Oct 57)

RADIO ELEMENT	% *
Radiocesium	53
Radiostrontium	9
Trivalent rare earths (including yttrium)	46
Other	0
Total beta count (c/m/5ml)	20

* Sum of percentages total 108%

EXPERIMENT 20
COAGULATION OF CONTAMINATED WATER WITH FERRIC CHLORIDE AND LIME

DATE: 17 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation with ferric chloride and limestone.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 115 ppm, total hardness 220 ppm, pH 7.7, turbidity 20 ppm, activity unfiltered 51 c/m/5ml, and activity filtered 49 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add coagulant and coagulant aid.
3. Rapid mix 5 min at 115 rpm.
4. Slow mix 15 min at 28 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	FeCl ₃ (ppm)	CaCO ₃ (ppm)	After Coagulation and Filtration			Dissolved Activity Removal (%)	Overall Activity Removal (%)
			Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity (c/m/5ml)	
1	20	40	123	7.3	230	44	14
2	40	60	123	7.2	230	47	8
3	60	85	114	7.1	240	47	8
4	80	115	102	7.0	240	44	14
5	100	135	99	6.8	240	44	14
6	125	160	99	7.1	250	35	31
7	150	185	96	6.9	260	40	22
8	175	210	83	6.7	250	44	14
9	200	250	78	6.4	250	35	31

NOTE: The coagulated water from the above experiment was composited, settled 18 hours, and then filtered through a Katadyn unit. The settled water counted 48 c/m/5ml, and the filtrate counted 42 c/m/5ml; the overall removal of activity from raw water to final filtrate being computed as 18%.

RADIOCHEMICAL DATA (Filtrate Peak r 5, 1 Oct 57)

RADIO ELEMENT	#
Radiocesium	17
Radiostroptium	13
Trivalent rare earths (including yttrium)	67
Other	3
Total beta count (c/m/sec)	22

EXPERIMENT 21
COAGULATION OF CONTAMINATED WATER WITH FERRIC CHLORIDE AND LIME

DATE: 17 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation with ferric chloride and lime.

CONTAMINANT: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 195 ppm, total hardness 220 ppm, pH 7.7, turbidity 20 ppm, activity unfiltered 51 c/m/5ml, and activity filtered 49 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add coagulant and coagulant aid.
3. Rapid mix 5 min at 115 rpm.
4. Slow mix 15 min at 28 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	FeCl ₃ (ppm)	Ca(OH) ₂ (ppm)	After Coagulation and Filtration			Dissolved		Overall
			Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity (c/m/5ml)	Activity Removal (%)	
1	20	11	110	7.1	235	42	14	18
2	40	22	101	7.3	225	46	6	10
3	60	34	89	7.3	230	44	10	14
4	80	45	88	7.2	220	46	6	10
5	100	56	89	7.2	230	45	8	12
6	125	70	93	7.3	245	46	6	10
7	150	84	88	7.3	240	41	16	20
8	175	98	54	7.7	235	47	4	8
9	200	112	40	8.0	230	41	16	20

EXPERIMENT 22
DECONTAMINATION OF CONTAMINATED WATER BY TREATMENT WITH CLAY

DATE: 18 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by treatment with clay.
CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 160 ppm, total hardness 240 ppm, pH 8.1, turbidity 20 ppm, activity unfiltered 55 c/m/5ml, and activity filtered 51 c/m/5ml.

PROCEDURE:

1. Add desired amount of clay to each beaker.
2. Add 600 ml contaminated water to each beaker.
3. Agitate desired length of time at 210 rpm.
4. Settle.
5. Filter through Whatman 2 filter paper.
6. Analyze for activity.

Beaker	Clay		Agitation Time (Min)	Activity After Filtration (c/m/5 ml)	Dissolved Activity Removal (%)		Overall Activity Removal (%)
	Type	PPM					
1	Belvoir	500	30	47	8		15
2	"	1000	30	46	10		16
3	"	1500	30	50	2		9
4	"	500	60	48	6		13
5	"	1000	60	47	8		15
6	"	1500	60	49	4		11
7	Conasauga	1500	30	36	29		39
8	"	1500	60	47	8		15

EXPERIMENT 23
DECONTAMINATION OF CONTAMINATED WATER BY COAGULATION,
FILTRATION, AND ION EXCHANGE IN SERIES

DATE: 19 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by coagulation, filtration, and ion exchange in series.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 142 ppm, total hardness 246 ppm, pH 7.3, turbidity 20 ppm, activity unfiltered 57 c/m/5ml, and activity filtered 48 c/m/5ml.

PROCEDURE:

1. Coagulate 4 liters of contaminated water with 100 ppm ferric chloride and 150 ppm limestone.
2. Settle.
3. Filter through Katadyn unit.
4. Pass filtrate through ion exchange beds; (a) Dowex 50-X8 (cation resin on hydrogen cycle) only, (b) Dowex 2-X7.5 (anion resin on hydroxyl cycle) only, (c) Rohm and Haas MB-3 only, and (d) Dowex 50-X8 and Dowex 2-X7.5 in series.

Item	Turbidity (ppm)	Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity (c/m/5ml)
Filtrate from Katadyn Unit	0	102	7.0	264	43
Effluent from Cation Exchanger Only	-	Neg.	3.5	5	24
Effluent from Anion Exchanger Only	-	265	10.2	110	4
Effluent from Mixed Bed Exchange Only	-	6	5.8	0	0
Effluent from Cation and Anion Exchanger in Series	-	4	6.0	2	0

DECONTAMINATION SUMMARY

Process	Dissolved Activity Removal (%)	Overall Activity Removal (%)
1. Coagulation Plus Filtration	10	25
2. Process 1 Plus Cation Exchange	50	58
3. Process 1 Plus Anion Exchange	92	93
4. Process 1 Plus Mixed Bed Exchange	100	100
5. Process 1 Plus Cation Exchange and Anion Exchange in Series	100	100

EXPERIMENT 24
DECONTAMINATION OF CONTAMINATED WATER BY LIME-SODA SOFTENING

DATE: 20 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by softening with lime-soda.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 145 ppm, total hardness 260 ppm, pH 7.8, turbidity 25 ppm, activity filtered 49 c/m⁵ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add lime and soda.
3. Rapid mix 5 min at 144 rpm.
4. Slow mix 20 min at 30 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	Ca(OH) ₂ (ppm)	Na ₂ CO ₃ (ppm)	After Softening and Filtration			Dissolved Activity Removal (%)	
			Alkalinity (ppm)	pH	Total Hardness (ppm)		
1	103	103	220	9.8	140	39	20
2	137	137	160	10.2	100	37	25
3	171	171	160	10.4	85	30	39
4	205	205	140	10.4	50	32	35
5	239	239	180	10.5	80	28	43

EXPERIMENT 25
DETERMINATION OF CONTAMINATED WATER BY LIME-SODA
SOFTENING (AT CONSTANT DOSAGE OF SODA)

DATE: 23 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by softening with lime-soda; at a constant soda dosage.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 154 ppm, total hardness 268 ppm, pH 7.7, turbidity 200 ppm, activity unfiltered 61 c/m/5ml, and activity filtered 47 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add lime and soda.
3. Rapid mix 5 min at 115 rpm.
4. Slow mix 20 min at 30 rpm.
5. Settle 30 min.
6. Filter through Whatman 42 filter paper.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	Ca(OH) ₂ (ppm)	Na ₂ CO ₃ (ppm)	After Softening and Filtration			Dissolved		Overall
			Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity (c/m/5ml)	Activity Removal (%)	
1	103	50	160	9.3	168	41	13	33
2	137	50	150	9.7	160	33	30	46
3	171	50	250	10.2	170	38	19	38
4	205	50	300	10.2	170	36	23	41
5	239	50	250	10.2	176	32	32	48

EXPERIMENT 26
DECONTAMINATION OF CONTAMINATED WATER BY SLURRYING WITH STEEL WOOL

DATE: 20 July 1957

OBJECTIVE: To determine the removal of activity from contaminated water by slurring with steel wool.

CONTAMINATED WATER: Supernatant from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Activity filtered 42 c/m/5ml.

PROCEDURE:

1. Add 1 quart contaminated water to a beaker.
2. Add 1 shredded fine grade steel wool pad (16.4 grams).
3. Agitate 30 min at 30 rpm.
4. Filter through Whatman 42 filter paper.
5. Analyze for activity.

Filtrate Count (c/m/5 ml)	Dissolved Activity Removal (%)
43	0

EXPT. PART 21
DECONTAMINATION OF CONTAMINATED WATER BY ADSORPTION

DATE: 22 July 1977
 OBJECTIVE: to determine the removal of activity from contaminated water by adsorption with toilet paper, pine saw dust, oak saw dust, coffee grounds, and red soil.
 CONTAMINATED WATER: Streamwater from mixing 250 gallons of tap water with 208 lbs of soil collected 30 yards northeast of ground zero.
 ANALYSIS OF CONTAMINATED WATER: Alkalinity 140 ppm, total hardness 244 ppm, pH 8.0, turbidity 28 ppm, activity unfiltered 53 c/m/5ml.

- PROCEDURE:
1. Add 700 ml contaminated water to each beaker.
 2. Add adsorbent.
 3. Mix 30 min at 84 rpm.
 4. Settle 20 min.
 5. Filter through paper towel in strainer.
 6. Analyze for activity.

Beaker	Adsorptive Agent	Amount	Activity of Filtrate (c/m/5ml)	Overall Activity Removal (%)
1	Toilet Paper	4 Squares	41	23
2	Pine Saw Dust	2 Teaspoons	48	9
3	Oak Saw Dust	2 Teaspoons	47	11
4	Coffee Grounds	2 Heaping Teaspoons	34	36
5	Red Soil	2 Heaping Teaspoons	30	43

EXPERIMENT 28
SERIES LEACHING OF SOIL

DATE: 23 July 1954
 OBJECTIVE: To determine the removal of activity from soil collected 30 yards northeast of ground zero, by successive series leaching with water.
 CONTAMINANT: Soil collected 30 yards northeast of ground zero.

PROCEDURE:

1. Add 60 grams of soil to a beaker.
2. Add 600 ml distilled water.
3. Agitate 30 min at 42 rpm.
4. Settle 1 hour.
5. Filter sample of supernatant and analyze for activity.
6. Decant supernatant to another beaker.
7. Add 600 ml distilled water to sludge.
8. Add 60 grams of soil to decantate.
9. Agitate contents of both beakers 30 min at 42 rpm.
10. Settle 1 hour.
11. Filter sample of both supernatants and analyze for activity.

Treatment	Dissolved Activity (c/m/5 ml)
1. Water slurried with soil	52
2. Water slurried with sludge from treatment 1	21
3. Water from treatment 1 slurried with additional soil	108

EXPERIMENT 29
LEACHING OF SAMPLES OF SELECTED RADIOACTIVE DEBRIS

DATE: 23 July 1957

OBJECTIVE: To determine the removal of activity from selected samples of radioactive debris by leaching with water.

CONTAMINANTS:

- (1) Sample of fallout from station 8 sized to $\leq 5 \mu$, 196 c/m/0.5 gram,
- (2) Sample of fallout from station 7, sized to $\leq 5 \mu$, 830 c/m/0.5 gram.

PROCEDURE:

1. Add 3.75 grams contaminant to beaker 1. Add 2.40 gram contaminant 2 to beaker 2.
2. Add 3.5 ml distilled water to beaker 1. Add 240 ml distilled water to beaker 2.
3. Agitate 30 min.
4. Filter through Whatman 42 filter paper.
5. Analyze for activity.

FALLOUT SAMPLE	DISSOLVED ACTIVITY (c/m/5ml)
1. Station 8, sized to $\leq 5 \mu$	3
2. Station 7, sized to $\leq 5 \mu$	11

EXPERIMENT 30
DECONTAMINATION BY LIME-SODA SOFTENING

DATE: 9 December 1957

OBJECTIVE: To determine the removal of activity from contaminated Shenandoah River water by lime-soda softening.

CONTAMINATED WATER: Supernatant from mixing 6.5 gallons of Shenandoah River with 5.4 lbs of soil collected 30 yards northeast of ground zero.

ANALYSIS OF CONTAMINATED WATER: Alkalinity 118 ppm, total hardness 204 ppm, pH 8.5, turbidity 50 ppm, activity unfiltered 16 c/m/5ml.

PROCEDURE:

1. Add 600 ml contaminated water to each beaker.
2. Add lime and soda.
3. Rapid mix 5 mins at 115 rpm.
4. Slow mix 20 mins at 28 rpm.
5. Settle 5 mins.
6. Filter through millipore filter.
7. Analyze for alkalinity, hardness, pH, and activity.

Beaker	Ca(OH) ₂ (ppm)	Na ₂ CO ₃ (ppm)	After Softening and Filtration			Overall Activity Removal (%)
			Alkalinity (ppm)	pH	Total Hardness (ppm)	Activity ** (c/m/5ml)
2	105	40	70	9.4	116	11
3	132	50	82	9.4	100	11
4	160	60	80	9.4	50	11
5	185	70	77	9.5	48	12
6	211	80	76	9.5	66	11
7	265*	100	232	9.5	160	11
8	317*	120	240	9.5	156	13

* Samples 7 and 8 were grossly overdosed for test purposes only.

** Counting Geometry 5.5%

Category 16 - Water Supply and Sanitation

DISTRIBUTION FOR USAERDL REPORT 1569-TR

TITLE Solubility Characteristics of Radioactive Bomb Debris in Water
and Evaluation of Selected Decontamination Procedures

DATE OF REPORT 12 Feb 59 PROJECT 8-75-07-460 CLASSIFICATION Unc1

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